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CONTENTS AND INDEX.

VOLUME XX.

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CONTENTS.

VOL. XX. January–June, 1898.

For alphabetical index, see page v

No. 1. JANUARY.

PAGE

Notes on Aluminum. *Jesse M. Smith* 1
Discussion. *H. G. Field, Alex. Dow, W. J. Keep, A. George Mattsson, Jesse M. Smith* 19
Hydraulic Rams. *J. Richards* 27
Discussion. *Messrs. Molera, Dickie, Wagoner, Richards* 45
The Geology of Helena, Montana, and Vicinity. *Prof. L. S. Griswold* 51
Recent Designs in Steamship Construction upon the Great Lakes. *Richard L. Newman* 69
Discussion. *Joseph R. Oldham, A. H. Raynal, John P. Johnston, James Ritchie, Capt. J. V. Tuttle, Wm. B. Cowles, R. L. Newman, John W. Seaver* 79
The Diesel Motor. *Col. E. D. Meier* 86
Association of Engineering Societies 105
Proceedings.

No. 2. FEBRUARY.

The Holding Power of Nails in Douglas Spruce (Oregon Pine) and in Redwood (Sequoia Sempervirens). *Prof. Frank Soulé* 115
Discussion. *Messrs. Molera, Percy, Soulé, Henny, Grunsky, Storey* 126
Modern Gas Engineering. *M. S. Greenough* 130
Discussion. *W. R. Warner, M. S. Greenough, E. P. Roberts, W. C. Parmley, R. L. Newman, Prof. C. F. Mabery* 142
History of the Stone Arch. *Prof. Malverd A. Howe* 146
Proceedings.

No. 3. MARCH.

Frontispiece.—Portrait of Randell Hunt.
The Erection of Metallic Bridges. *Frank P. McKibben* 171
Discussion. *Messrs. J. Parker Snow, B. W. Guppy, Horace J. Howe, F. P. McKibben* 198

PAGE

Rainfall and Run-Off in Relation to Sewerage Problems. *Walter C. Parmley* 204
Discussion. *Messrs. M. E. Rawson, C. G. Force, Jr.* 224
Effects of Heating and Working on Iron and Steel. *Prof. H. E. Smith* 226
Brick Paving. *Irving E. Howe* 235
Proceedings.

No. 4. APRIL.

An Investigation of the Strength of Columns Leading to Some New Formulas. *Carl G. Barth* 239
Some Instances of Piles and Pile-Driving, New and Old. *Horace J. Howe* 257
Discussion. *Messrs. George B. Francis, S. E. Tinkham, James W. Rollins, Jr., Frank W. Hodgdon, Carson, Sidney Smith, Rudolph Hering, Spencer Cosby, Prof. W. M. Patton, Horace J. Howe* 294
Proceedings.

No. 5. MAY.

Address Before the Montana Society of Engineers. *C. W. Goodale* 313
The Canyon Ferry Dam. *Theron M. Ripley* 331
Discussion. *Messrs. Wilson, Parker, Page, Herron* 336
Properties of Concrete Under Compressive Stress. *David Molitor* 341
The Steel Frame of the St. Louis Coliseum. *E. W. Stern* 353
Proceedings.

No. 6. JUNE.

Co-ordinate Survey of the City of Boston. *Frank O. Whitney* 365
The Portland Cement Industry of the World. *Bernard L. Green* 391
Discussion. *Messrs. S. J. Baker, Green, D. L. Clements, C. B. Stowe, E. E. Boalt, J. C. Robinson* 411
Proceedings.

INDEX.

VOL. XX, January-June, 1898.

The six numbers were dated as follows:

No. 1, January.	No. 3, March.	No. 5, May.
No. 2, February.	No. 4, April.	No. 6, June.

ABBREVIATIONS.—P = Paper; D = Discussion; I = Illustrated.
Names of authors of papers, etc., are printed in *italics*.

PAGE

Address before the Montana Society of Engineers. *C. W. Goodale.* I., May, 313
Aluminum, Notes on——. *Jesse M. Smith*..............P., D., Jan., 1
Arch, History of the Stone——. *Prof. Malverd A. Howe*..P., I., Feb., 146

Boston, Co-ordinate Survey of the City of——. *Frank O. Whitney.* P., I., June, 365
Brick Paving. *Irving E. Howe*..........................P., March, 235
Bridges, Erection of Metallic——. *Frank P. McKibben.* P., D., I., March, 171

Canyon Ferry Dam. *Theron M. Ripley*...............P., D., I., May, 331
Cement, The Portland——Industry of the World. *Bernard L. Green.* P., June, 391
Columns, An Investigation of the Strength of——Leading to Some New Formulas. *Carl G. Barth*....................P., I., April, 239
Compressive Stress, Properties of Concrete Under——. *David Molitor.* P., I., May, 341
Concrete, Properties of——Under Compressive Stress. *David Molitor.* P., I., May, 341
Co-ordinate Survey of the City of Boston. *Frank O. Whitney.* P., I., June, 365

Dam, The Canyon Ferry——. *Theron M. Ripley*......P., D., I., May, 331
Diesel Motor. *Col. E. D. Meier*.........................P., I., Jan., 86

Effects of Heating and Working on Iron and Steel. *Prof. H. E. Smith*...P., March, 226
Erection of Metallic Bridges. *Frank P. McKibben*..P., D., I., March, 171

Frame, The Steel——of the St. Louis Coliseum. *E. W. Stern.* P., I., May, 353

Gas Engineering, Modern——. *M. S. Greenough*.....P., D., I., Feb., 130
Geology of Helena, Montana, and Vicinity. *Prof. L. S. Griswold.* P., I., Jan., 51
Goodale, C. W. Address Before the Montana Society of Engineers. I., May, 313
Green, Bernard L. The Portland Cement Industry of the World. P., D., June, 391
Greenough, M. S. Modern Gas Engineering..........P., D., I., Feb., 130
Griswold, Prof. L. S. The Geology of Helena, Montana, and Vicinity, P., I., Jan., 51

Heating and Working on Iron and Steel, Effects of——. *Prof. H. E. Smith*..........P., March, 226
Helena, Montana, Geology of——and Vicinity. *Prof. L. S. Griswold.* P., I., Jan., 51
History of the Stone Arch. *Prof. Malverd A. Howe*......P., I., Feb., 146
Holding Power of Nails in Douglas Spruce (Oregon Pine), and in Redwood (Sequoia Sempervirens). *Prof. Frank Soulé.* P., D., I., Feb., 115
Howe, Horace J. Some Instances of Piles and Pile-Driving, New and Old..........P., D., I., April, 257
Howe, Irving E. Brick Paving..........P., March, 235
Howe, Malverd A. History of the Stone Arch..........P., I., Feb., 146
Hydraulic Rams. *J. Richards*..........P., D., I., Jan., 27

Investigation of the Strength of Columns Leading to Some New Formulas. *Carl G. Barth*..........P., I., April, 239
Iron and Steel, Effects of Heating and Working on——. *Prof. H. E. Smith*..........P., March, 226

McKibben, Frank P. The Erection of Metallic Bridges. P., D., I., March, 171
Meier, Col. E. D. The Diesel Motor..........P., I., Jan., 86
Metallic Bridges, Erection of——. *Frank P. McKibben.* P., D., I., March, 171
Modern Gas Engineering. *M. S. Greenough*..........P., D., I., Feb., 130
Molitor, David. Properties of Concrete Under Compressive Stress. P., I., May, 341
Montana Society of Engineers, Address before the——. *C. W. Goodale*..........I., May, 313
Motor, The Diesel——. *Col. E. D. Meier*..........P., I., Jan., 86

Nails, The Holding Power of——in Douglas Spruce (Oregon Pine), and in Redwood (Sequoia Sempervirens). *Prof. Frank Soulê.* P., D., I., Feb., 115
Newman, Richard L. Recent Designs in Steamship Construction Upon the Great Lakes..........P., D., I., Jan., 69
Notes on Aluminum. *Jesse M. Smith*..........P., D., Jan., 1

Parmley, Walter C. Rainfall and Run-Off in Relation to Sewerage Problems....................................P., D., I., March, 204
Paving, Brick. *Irving E. Howe*..........................P , March, 235
Piles, Some Instances of——and Pile-Driving, New and Old. *Horace J. Howe*....................................P., D., I., April, 257
Portland Cement Industry of the World. *Bernard L. Green.* P., D., June, 391
Properties of Concrete Under Compressive Stress. *David Molitor.* P., I., May, 341

Richards, J. Hydraulic Rams.......................P., D., I., Jan., 27
Rainfall and Run-Off in Relation to Sewerage Problems. *Walter C. Parmley*....................................P., D., I., March, 204
Rams, Hydraulic. *J. Richards*.......................P., D., I., Jan., 45
Recent Designs in Steamship Construction Upon the Great Lakes. *Richard L. Newman*................................P., D., I., 69
Ripley, Theron M. The Canyon Ferry Dam..........P., D., I., May, 331

Sewerage Problems, Rainfall and Run-Off in Relation to——. *Walter C. Parmley*...................................P., D., I., March, 204
Smith, Prof. H. E. Effects of Heating and Working on Iron and Steel..P., March, 226
Smith, Jesse M. Notes on Aluminum.................. P., D., Jan., 1
Some Instances of Piles and Pile-Driving, New and Old. *Horace J. Howe*.......................................P., D., I., April, 257
Soulé, Prof. Frank. The Holding Power of Nails in Douglas Spruce (Oregon Pine), and in Redwood (Sequoia Sempervirens). P., D., I., Feb., 115
Steamship Construction, Recent Designs in——Upon the Great Lakes. *Richard L. Newman*...................................P., D., I., 69
Steel, Effects of Heating and Working on Iron and——. *Prof. H. E. Smith*..P., March, 226
Steel Frame of the St. Louis Coliseum. *E. W. Stern*......P., I., May, 353
St. Louis Coliseum, The Steel Frame of the——. *E. W. Stern.* P., I., May, 353
Stone Arch, History of the——. *Prof. Malverd A. Howe*..P., I., Feb., 146
Strength of Columns, An Investigation of the——Leading to Some New Formulas. *Carl G. Barth*....................P., I., April, 239
Survey, Co-ordinate——of the City of Boston. *Frank O. Whitney.* P., I., June, 365

Whitney, Frank O. Co-ordinate Survey of the City of Boston. P., I., June, 365

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NOTES ON ALUMINUM.

BY JESSE M. SMITH, MEMBER DETROIT ENGINEERING SOCIETY.

[Read before the Society, October 22, 1897.*]

THE following notes, while not entirely new or unpublished, may, however, be of interest now that aluminum is becoming a common metal.

I am indebted to Mr. Alfred E. Hunt, president of the Pittsburg Reduction Company, for the information which forms the basis of this paper, and I know of no better authority on the subject, taken in all its branches, than he.

Aluminum, or aluminium, as it is more frequently called in Europe, is a metal that has been known for very many years, but its properties have received much closer study of late since it has become a commercial or common metal.

PURE AND IMPURE ALUMINUM.

Commercial metal is never chemically pure, and until within recent years, nearly all that of which the properties had been described, had at least 4 per cent.—in many cases 6 per cent. or 8 per cent.—of impurities. These materially altered the characteristics from those of the purer metal, with not over 2 per cent. or at most 3 per cent. of impurities, which is ordinarily sold in the market to-day.

The impurities almost always found with aluminum are silicon and iron.

The silicon present with aluminum exists in two forms, one

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seemingly combined with the aluminum, as combined carbon exists in white pig iron, and the other in an allotropic graphitoidal form. These two forms of silicon seem to exert somewhat different effects; the combined form of the element rendering the metal much harder than the graphitoidal variety. The combined silicon ordinarily preponderates, being from 55 per cent. to 80 per cent. of the total silicon in the average metal of between 98 per cent. and 99 per cent. purity.

For many purposes, the purest aluminum cannot be so advantageously used as that containing 3 per cent. or even 4 per cent. of impurity, as the pure metal is very soft, and not so strong as the less pure. It is only where extreme malleability, ductility, sonorousness, or non-corrodibility is required, that the purest metal should be chosen. For most purposes, a small percentage of other elements than silicon and iron is advantageous in producing hardness, rigidity and strength—constituents that will not detract from the non-corrodibility of the metal as much as do those natural impurities that come from the ore and apparatus—additions that will give the aluminum a better color and greater strength and hardness, with proportionately less sacrifice of malleability, ductility, etc.

COLOR OF ALUMINUM.

Pure aluminum is white, with a decided bluish tint. This becomes much more marked upon exposure, when a thin film of white oxide on its surface prevents further tarnishing from the air, but seems to give, by contrast to the metal as a background, an enhanced bluish tint.

ACTION OF HEAT ON ALUMINUM.

Aluminum melts at about 1200° F., but becomes pasty at a temperature of about 1000° F.; and, indeed, loses its tensile strengh and very much of its rigidity at a temperature of 400° to 500° F., but its strength returns when the temperature falls. Heating serves as an annealing operation, and reduces permanently only the higher tensile strength produced by cold rolling or othewise cold working the metal. Aluminum does not volatilize at any temperature ordinarily produced by the combustion of carbon, even though the high temperature be kept up for a considerable number of hours. It, however, absorbs a very large amount of occluded gases under such treatment. In the high temperature of the electric furnace, however, it is claimed that there is considerable volatilization of aluminum, and that small

buttons of the metal have been found in and on the linings of the furnace.

Under heat, the coefficient of linear expansion of $\frac{3}{8}$ inch round aluminum rods of 98.50 per cent. purity is 0.0000206 per degree Centigrade between the freezing and boiling points of water; while that of iron is only 0.0000122.

Taking silver as 100, and copper as 73.6, unannealed aluminum of 98.50 per cent. purity has a coefficient of thermal conductivity of 37.96; while that of the same wire, annealed, is 38.87.

ELECTRICAL PROPERTIES OF ALUMINUM.

Aluminum stands next to silver, copper and gold, as a conductor of electricity. The electrical conductivity of silver being taken at 100, and that of copper at 90, pure annealed aluminum has an electrical conductivity of about 50. These facts, taken into consideration with the lightness of the metal as compared with silver, gold and copper, are already leading to a quite extensive use of aluminum in electrical apparatus.

MECHANICAL PROPERTIES OF ALUMINUM.

The pure metal is very tough, and, in breaking by bending backward and forward, often appears distinctly fibrous in fracture. The lack of rigidity and hardness which the metal exhibits is a serious obstacle to its adaptability for many purposes, although both its stiffness and its hardness are very much increased by the addition of a few per cent. of impurities or alloy, and especially by cold-hammering, cold-rolling, drop-forging, or the like. It can be safely stated, as a general rule, that the purer the aluminum the softer and less rigid it is.

Pure aluminum, when properly treated, is a very malleable and ductile metal. It can readily be rolled into sheets 0.0005 of an inch thick, or be beaten into leaf nearly as thin as gold leaf, or be drawn into the finest of wire. Pure aluminum stands third in the order of malleability, being exceeded only by gold and silver; and seventh in the order of ductility, being exceeded by gold, silver, platinum, iron, softest steel and copper. Both malleability and ductility are greatly impaired by the presence of the two common impurities, silicon and iron.

Aluminum can be rolled or hammered cold, but the metal is most malleable at between 200° and 300° F., and should be heated to this point for rolling or breaking down from the ingot to the best advantage. Even then considerable power is required, fully as much as for hot-rolling of hard steel of similar section, although not nearly as much draft can be placed upon the rolls as in hot-

rolling hard steel. Like silver and gold, aluminum stiffens up remarkably by working, which greatly increases its hardness and its tensile strength, and decreases its malleability and ductility. Aluminum requires to be frequently annealed in working.

When the metal is hardened by rolling, forging, drop-forging, stamping, drawing, etc., it may be turned out very rigid, and will then answer excellently for purposes where the annealed metal would be entirely too soft, too weak, or lacking in rigidity or elasticity. Especially is this true of aluminum alloyed with a few per cent. of titanium, copper, iron, silicon, or the like.

ANNEALING ALUMINUM.

To anneal aluminum it should be placed in a muffle, and a low and even temperature, such as will show an even, red heat in a piece of iron or steel placed in the muffle, when viewed at twilight or on a dark day, should be maintained. The aluminum itself, however, should not appear at all red at this temperature. A ready test of this temperature is that the metal has been heated enough to char the end of a pine stick, which will leave a black mark on the plate as it is drawn across it.

WELDING AND SOLDERING ALUMINUM.

Aluminum can be easily and readily welded by the electric welding machines.

Until very lately, the lack of methods for successfully soldering and hardening aluminum was the greatest drawback to its introduction for many purposes. Soldering is done by the use of the blow-pipe and with ordinary hard or soft solder, or with pure zinc, or with an alloy of zinc and aluminum, as the soldering metal.

CASTING ALUMINUM.

Sound castings of aluminum can be readily made in dry sand molds. The aluminum should not be heated very much beyond the melting point, otherwise it seems to absorb gases which remain in the metal, preventing sound castings. In small quantities, the metal can be best melted in plumbago crucibles; but in large quantities it can be more economically melted in a reverberatory furnace with alumina or magnesia brick sides and alumina bottom. The furnace should have a tap-hole for drawing off the liquid metal into carbon-lined ladles. In no case need the metal be covered with a flux to assist in the fusion or to form a covering of slag. The molten metal flows readily, and not much larger gates are needed than for brass. Its shrinkage of 15-64

inch per foot is considerably greater than that of brass, which is about 6-64 inch per foot.

RESISTANCE OF ALUMINUM TO CORROSION.

As to the corrodibility of aluminum many erroneous statements have been printed. In the first place, aluminum is acted upon by the atmosphere, especially by moist atmosphere, and more especially still by moist salt atmosphere. The metal becomes covered by a very thin, almost imponderable, coating of oxide on the surface exposed to the atmosphere, and this coating seems to protect it from further oxidation. It is so thin that often it hardly interferes with any polish, and it does not materially change the weight of the metal. It does, however, increase the bluish tint of the metal, and gives it a leaden color. As compared with most metals, pure aluminum, under ordinary circumstances, withstands the action of wind and weather exceedingly well; and many uses to which the metal is now being successfully applied are based upon this fact. The presence of silicon in aluminum materially detracts from its power to withstand corrosion due to atmospheric influences. Metal with 4 per cent. or 5 per cent. of silicon, if severely exposed, very soon collects a thick coating of oxide upon it. The fact that pure aluminum is not acted upon by boiling water or by steam has led to its use by the New York Steam Company and others, as a packing or gasket in steam connections, where lead and similar metals have been rapidly cut out (especially where the water contained notable amounts of sulphur acids), as in parts of steam and water pumps and different steam joints.

Aluminum containing sodium is rapidly acted upon by hot water, the sodium being eaten out, leaving the aluminum spongy and porous. Aluminum is unaffected by either concentrated sulphuric or nitric acid. Unfortunately, however, these commercial acids almost always contain some little hydrochloric acid, which rapidly corrodes the aluminum, the chloride of aluminum first formed being changed into sulphate or nitrate, the free hydrochloric acid again acting more violently as it attacks the metal in a nascent state.

Aluminum is not acted upon by carbonic acid or carbonic oxide gas, nor by sulphureted hydrogen except at a red heat; but it is a peculiarity of the metal in a melted condition that it absorbs large quantities of these gases, much of which is again excluded as the metal cools.

Pure aluminum has neither taste nor odor, nor is it corroded

by any substances ordinarily used in culinary operations. It seems therefore, especially adapted, and is becoming considerably used, for cooking utensils.

The natural acid solvent for aluminum is hydrochloric acid. Solutions of the caustic alkalies, chlorine, bromine, iodine and fluorine also rapidly corrode it. Ammonia gas has very little action on the metal, except to turn it a gray color, but strong aqua-ammonia has a slight solvent action upon it.

OTHER PHYSICAL PROPERTIES OF THE METAL.

The specific gravity of aluminum, of course, is one of its most striking properties—a property on which many brilliant "castles in the air" have been built. It runs from 2.56 to 2.70; structural steel is 2.95 times heavier, copper 3.60 times, silver 4 times, lead 4.80 times, gold 7.70 times, and platinum 8.60 times heavier. Its lightness has suggested many uses, including the entire framework of air ships. There are, however, many strong woods which have a specific gravity below 1, weighing, therefore, only about one-third as much as aluminum; and, as woods can be selected that will by no means require three times the section of aluminum to give equal strength for frames, it does not seem that the metal will be much used for this purpose. Of course, in many cases a much thinner sheet or smaller section of aluminum could be used than of wood; but for purposes where rigidity as well as lightness is required, the parts of air ships could be much better made of wood than of aluminum.

STRENGTH OF ALUMINUM.

Cast aluminum has about the ultimate strength of cast iron in tension, but under compression it is comparatively weak.

The following table gives the average results of many tests of metal composed approximately of: Aluminum, 97 per cent. to 99 per cent.; silicon graphite, 0.10 per cent. to 1 per cent.; silicon, combined, 0.90 per cent. to 2.80 per cent.; iron, 0.04 per cent. to 0.20 per cent.

Tension tests	Castings	Sheet	Wire	Bars
Elastic limit, lbs. per sq. in.........	6,500	12,000	16,000 to 30,000	14,000
Ultimate strength, lbs. per sq. in.,	15,000	24,000	30,000 to 60,000	28,000
Reduction of area................	15%	35%	60%	40%

Compression tests (in cylinders with length twice the diameter):

Elastic limit, per sq. in..	3,500 lbs.
Ultimate strength, per sq. in.......................................	13,000 lbs.

The modulus of elasticity of cast aluminum is about eleven million; cold drawn aluminum wire, about nineteen million; aluminum sheets, about thirteen million.

Under transverse test, pure aluminum is not a very rigid metal. An inch square bar of good cast iron, supported on knife edges 4 feet 6 inches apart and loaded in center, will readily stand 500 pounds, with a deflection of not over 2 inches. A similar bar of aluminum would deflect more than 2 inches with a weight of 250 pounds, but the aluminum bar would bend nearly double before breaking, while the cast-iron bar wi l ordinarily break before the deflection has gone very much beyond 2 inches. Aluminum, to withstand strains, and especially to have good elasticity, should be alloyed with a few per cent. of impurities and cold-rolled, or otherwise worked cold. In this way it can be made nearly as strong and elastic as mild steel, section for section, and weight for weight will be much more rigid.

ALLOYS OF ALUMINUM AND COPPER.

Aluminum and copper from two series of valuable alloys: the aluminum bronzes, ranging from 2 per cent. to 12 per cent. aluminum with copper; and the copper hardened aluminum series with from 2 per cent. to perhaps 15 per cent. of copper with the aluminum. The aluminum bronze series is already beginning to assume an important position in the arts, and may very largely replace brass and other bronzes, and for some purposes take the place of steel. By adding 8 per cent. to 12 per cent. of aluminum to copper we obtain one of the densest, most finely grained and strongest metals known, a metal having a remarkably high ductility as compared with its tensile strength. A 10 per cent. bronze can readily and uniformly be made in forged bars, with 100,000 pounds per square inch tensile strength, with 60,000 pounds elastic limit per square inch, and with at least 10 per cent. elongation in 8 inches; and aluminum bronzes can be made to meet a specification of even 130,000 pounds per square inch tensile strength and 5 per cent. elongation in 8 inches. Such bronzes have a specific gravity of about 7.50, and are of a light yellow color. The 5 per cent. to 7 per cent. aluminum bronzes have from 8.30 to 8.0 specific gravity, and a handsome yellow color. They readily give 70,000 to 80,000 pounds per square inch tensile strength, with over 30 per cent. elongation in 8 inches, and with an elastic limit of over 40,000 pounds per square inch. Alloys of the latter character will probably be most used, especially for marine work. The fact that 5 per cent. to 7 per cent. bronzes can be rolled or hammered at a

red heat, under proper precautions which can readily be secured, will greatly extend their use. Metal of this character can be worked in almost every way in which steel can be worked, and has greater combined strength and ductility, and much greater power to withstand corrosion. By far the best results have been obtained by using the purest aluminum and purest copper. The presence of silicon in aluminum alloys makes a harder bronze, but one of much less comparative ductility and malleability. The presence of iron weakens and very seriously interferes with the value of bronze. Tin also is disadvantageous. The presence of zinc in the aluminum bronze is not so deleterious; in fact, it makes the best aluminum brasses, much better than those containing tin.

WORKING ALUMINUM BRONZE.

Aluminum bronze is among the hardest of the bronzes, and hardens considerably upon cold-working. This hardness, however, can readily be lowered by annealing at a red heat and plunging into cold water. Aluminum bronze can readily be worked in a lathe, as the chips, cutting clean, smooth and long, do not clog the tool. Aluminum bronze is a remarkably rigid metal under transverse strain, being much more rigid than ordinary brass, or even gun bronze. Under compression, its elastic limit is rather low, compared to its ultimate compressive strength, but the latter still much higher than that of any of the other bronzes, and there is a long period of gradual compression before finally giving way, making it a particularly safe metal under compression.

Aluminum bronze has excellent anti-friction qualities, owing to its finely grained texture and peculiar smooth and unctuous though hard surface, which resists abrasion remarkably. Attention has already been called to the anti-corrosive qualities of aluminum bronze; and as its electrical conductivity is higher than that of brass, it is especially well adapted for commutator bars in dynamos. It can be brazed and soldered nearly as well as brass.

CASTING ALUMINUM BRONZE.

Sound, clean castings of aluminum bronze can be safely and regularly made, either in sand molds or against chills, if the proper precautions are taken to avoid: first, oxidation; second, contamination from scum or a cinder composed of oxide of aluminum with a little copper in it; third, depressions, cracks, or strains due to shrinkage; fourth, the shutting in of gas into the castings. The first trouble, oxidation, is due to heating the metal too hot in the plumbago crucible. The copper should not be heated much

above its melting point before the addition of the aluminum, which at first absorbs much heat and rapidly thickens the metal, the aluminum being rapidly immersed in the copper to prevent its oxidation. Great care should then be taken in again bringing the metal up to the liquid condition, and the metal should be frequently stirred, for it suddenly acquires heat by the reaction of the alloying of the two metals, and, unless precautions are taken, the temperature will soon be brought to a white heat, when oxidation will seriously injure the bronze. The metal should have a cover of powdered charcoal to prevent oxidation, but no flux over its surface.

The second trouble, contamination from the scum, can be avoided by pouring from the melting furnace or pot into a hot ladle or pouring basin large enough to hold all the metal necessary to fill the mold and to allow the metal to pour out from the bottom of such a receptacle after giving sufficient time to allow the scum to come to the surface. A skim-gate should also be provided for each mold.

The third difficulty is caused by a peculiar red-shortness just after solidification, and also a contraction at solidification which causes the metal either to tear apart or to yield and cause depressions in the casting at more favorable spots, if any great resistance is experienced by the metal in contraction. This difficulty is overcome by giving bountiful allowance for the contraction, which can be done in several ways, each best adapted for certain conditions. The cores should be made of a yielding character, using resin or other suitable substance with coarse sand, that will yield to slight pressure. Unyielding iron core rods should be dispensed with as far as possible. Green sand cores will give good results in some cases. Other expedients to gain the same ends will be readily suggested by skilled molders.

The troubles due to shrinkage are avoided by having the "risers" or "feeding heads," with flaring openings, large in section, often larger than the castings they are intended to feed, and if necessary refilling the feeding heads, in some cases several times over. In this way the casting will solidify first, drawing metal to supply its shrinkage from the still fluid riser having a level higher than the casting itself, so that the metal will flow down into it. The gates to the mold should be sufficient in number and so arranged that they can be filled with the metal as cold as it will pour and give full castings. The considerable amount of scrap occasioned by the large risers can be remelted without loss of aluminum, and, indeed, is improved in quality by the process of remelting.

To prevent the shutting of gas into the castings, dry sand should be used, and the molds should be well vented by the ordinary precautions taken by founders for this purpose. Although it requires skill and experience to carry out successfully the conditions outlined, sound, clean castings, even of the most difficult sections of aluminum bronze can be made regularly, with no more wasters than in casting the ordinary brass, and without the difficulty of a copious liberation of gas at the moment of solidification, as is the case with steel. In fact aluminum bronze with its low pouring temperature, is especially applicable for massive and heavy castings.

ALUMINUM WITH IRON AND STEEL.

Aluminum combines with iron in all its proportions. None of the alloys, however, have proved of value, except those of small percentages of aluminum with steel, cast iron and wrought iron. So far as experiments have yet gone, while iron hardens aluminum other elements can be better employed for this purpose, and its presence is regarded as entirely a deleterious impurity to be avoided if possible.

The addition of from $\frac{1}{3}$ pound to 2 pounds of aluminum to a ton of steel gives the advantage of quieting the metal in the mold and producing ingots with much sounder tops, so that the scrap due to crop ends is materially lessened, a saving which much more than pays for the cost of the aluminum added. The amount to be added varies with the character and condition of the steel. With well-melted steel, low in carbon, the proportion of from $\frac{1}{3}$ to $\frac{1}{2}$ pound to the ton seems to give the best results; any larger proportion causing the metal to pipe and producing an excess of crop-end scrap.

In steel castings, the benefit from the use of a small percentage of aluminum, ordinarily in the proportion of from 2 to 3 pounds per ton, has become widely recognized. The additions of aluminum are almost always made by throwing the metal, in pieces weighing a few ounces each, into the ladle as the steel is pouring into it.

For cast iron from 2 to 5 pounds of aluminum per ton is put into the metal as it is being poured from the cupola or melting furnace. To soft gray No. 1 foundry iron it is doubtful if the metal does much good, except, perhaps, in the way of keeping the metal melted for a longer time; but where difficult castings are to be made, where much loss is occasioned by defective castings, or where the iron will not flow well or give sound and strong castings,

the aluminum certainly in many cases allows of better work being done, and gives stronger and sounder castings with a closer grain, and hence much easier tooled. The tendency of aluminum is to change combined carbon to graphitic, and it certainly lessens the tendency of the metal to chill. Aluminum in proportions of 2 per cent. and over materially decreases the shrinkage of cast iron.

CLAY AS A SOURCE OF ALUMINUM.

Contrary to the understanding of many persons, aluminum has never been found in nature in the metallic state; and yet the general statement made by Professor Richards is true, that "there is no other metal on the earth so widely scattered, and that occurs in such abundance." This statement, however, has been interpreted by the public to the effect that therefore all these varied minerals containing aluminum are equally applicable as ores from which to extract the metal. Particularly have they considered that the clays or silicates of aluminum are the specially chosen ores for the production of that metal. A consideration of the comparative constituents of clay with those of the minerals given below shows the disadvantage of the richest of clays, as aluminum ores, when compared with the richer and purer oxides, fluorides and sulphates, which are now the chief sources of aluminum.

Bauxite ($Al_2H_6O_6$), soft and grandular; with 50 to 70 per cent. oxide of aluminum and with only a few per cent. of accidental impurities besides the water of hydration.

Corundum (Al_2O_3), very hard and crystalline; with 93 per cent. alumina and ordinarily very free from impurities, but so hard and crystalline, and withal so valuable for other purposes, as not to be at present used as an aluminum ore.

Diaspore ($Al_2O_3+H_2O$), hard and crystalline; with 65 to 85 per cent. alumina and ordinarily very pure.

Cryolite ($Al_2Fl_6+6NaFl$); with 40 per cent. aluminum fluoride and 60 per cent. sodium fluoride.

Aluminite ($Al_2SO_6+9H_2O$); with some 30 per cent. of alumina in a condition to be cheaply purified by solution, filtration and roasting.

Gibbsite ($Al_2O_3+3H_2O$), stalactitic; with about 65 per cent. alumina.

In comparison with these, the clays vary from tribasic silicates of alumina to pentacid silicates, minerals with at best 65 per cent. alumina and 35 per cent. silica; while the more common clays contain from 50 to 70 per cent. silica and only from 50 to 35 per cent. alumina. Pure kaolin contains 39 per cent. alumina,

carrying about 20 per cent. aluminum with 40 per cent. silica and 14 per cent. water. Now silica is much more easily reduced than alumina, and by all the methods of reduction this large percentage of silica must be separated from the alumina before the reduction is commenced, else a large percentage of energy used in reduction will be expended in reducing a troublesome impurity instead of in reducing the alumina to aluminum.

One fact, however, seems to be favorably prominent in the prospect of fat clays (like the kaolins) being used as aluminum ores; that is, that concentrated cold sulphuric acid dissolves the alumina out of most clays, leaving the silica insoluble. This fact has not yet been made use of on a commercial scale, but in the future, when there is a large demand, it may make clays available as ores of aluminum.

PREPARING ALUMINUM ORE FOR REDUCTION.

Bauxite is the mineral most used at present for the manufacture of alumina, and it probably will continue to be the most economical ore, for the reason that it is soft, easily ground and easily decomposed to separate the impurities of silica and iron. The mineral occurs in great abundance in the South; in Tennessee, Virginia, North and South Carolina, Georgia and Alabama, and also in Arkansas. Very pure bauxites can be laid down in quantities in Pittsburg at a cost of between \$9 and \$10 per ton; and, with only the cost of mining and transportation, can be put on cars nearest the mines in many cases at a cost of less than \$2.50 per ton.

The general method of purification of the ore is to calcine the bauxite with just sufficient sodium carbonate to form sodium aluminate ($Al_2O_3+3Na_2O$). The incinerated mass is taken out of the furnace, ground and lixiviated with hot water, which takes the sodium aluminate into solution, leaving the silica and iron insoluble. The clear supernatant sodium aluminate solution is siphoned off, and the alumina is precipitated with carbonic acid gas. This forms sodium carbonate, which remains in solution, while the alumina settles out to the bottom of the tank. This is afterwards washed with hot water and dried.

METHODS OF ALUMINUM MANUFACTURE.

Aluminum cannot be reduced from its oxide by the aid of carbon as a reducing agent, because the temperature to which the intimate mixture of the solid carbon and the alumina has to be raised can be attained only by the highest heat of an open-hearth

furnace or in the electric furnace—at this temperature the aluminum reduced cannot itself be accumulated into a molten liquid mass, and can be retained only by cloaking it with a more stable metal like iron or copper.

Debarred from using carbon as the reducing agent under the ordinary conditions which make it the practicable and economical reagent in most metallurgical operations, experimenters have carefully tested the advantages of other and stronger reducing agents. So far, only one has proven commercially available, although there are many other agents capable of reducing the metal from its oxide. Metallic sodium reduces the metal from its chloride or from its fluoride salts with ease. Methods based upon the use of sodium as the reducing agent have until lately given not only the purest but the cheapest aluminum. These methods, however, of late have been succeeded by the cheaper and more direct processes of electrolysis of some of the aluminum salts or of the pure oxide.

THE HISTORY OF ALUMINUM PRODUCTION.

So far as history informs us, Wöhler, in 1827, first obtained metallic aluminum, reducing it by the aid of metallic potassium from aluminum chloride. The metal was a dry powder in a finely divided state. It was very impure, and was only a metallic curiosity. Deville, twenty-seven years later, in 1854, was the first to produce the metal in any quantity, or with any degree of purity.

It is curious to note that the first pure aluminum made was by electrolysis. Both Bunsen and Deville reduced the double chloride of aluminum and sodium by electricity generated by galvanic batteries. But at that time the dynamo was yet a machine of the future, and electrolysis was soon abandoned for the sodium process by the successful concerns in the manufacture of the metal, although experimental efforts have been made with electricity from that time to this. The first aluminum made in 1855 was valued at $90 per pound. In 1857, with the development of the sodium method of reduction, the price was lowered to from $28 to $32 per pound. In 1860 the price was again lowered to about $17 per pound, and from 1862 to 1887 the price ranged from $12 per pound upward, according to purity. In 1887 the price was reduced to $5 per pound; and it was at this price that the first metal was sold, made by the new concerns built during that year. In 1889 the Pittsburg Reduction Company reduced the price to $2 per pound. The English works of the Pittsburg Reduction Company commenced in 1890 to sell the metal in England at five shil-

ling ($1.21) per pound. In May, 1896, the price in New York was 35 cents per pound. In October, 1897, the price of No. 1—99 per cent. pure aluminum for rolling was 40 to 45 cents per pound, according to quantity. No. 1 ingots for remelting, 37 to 42 cents, and No. 2—90 per cent. pure, for remelting with iron or steel, 31 to 34 cents per pound.

About 1857 the famous works at Salindres, France, were established. These enjoyed the reputation of making not only the best but the greatest quantity of aluminum in the world. The care and skill shown, and the ingenious devices and precautions taken by the firm to prevent impurities in the metal by the cumbersome and expensive sodium process in which there were so many opportunities for the addition of impurities, were worthy of the highest praise. From 1874 to 1882 the French company at Salindres was the only concern making pure aluminum.

Early in 1888 the Alliance Aluminum Company started works at Wallsend-on-Tyne, England, using a process which was an innovation upon the Deville sodium process. It used the fluoride or the double fluoride of aluminum and sodium, cryolite, as the compound to be reduced instead of the chloride or the double chloride of the metal. Professor Nette, the managing director of the concern, also had a process for producing metallic sodium cheaply by allowing fused caustic soda to trickle over incandescent charcoal in a vertical retort. Some very excellent aluminum was produced at these works. They became involved, however, in a lawsuit, with the Aluminum Company, Limited, and the newer processes coming up caused them also to close their works, which have now been shut down for over a year.

ALUMINUM PRODUCTION BY ELECTRICITY.

The first actual reduction of aluminum in a metallic state on a practical scale, by the aid of electricity, electrically decomposing the chloride, was by Deville in 1854. Even then the idea was old, for Sir Humphry Davy, in 1810, publicly described the successful experiment made in 1807, in which he connected the negative pole of a battery of 1000 double plates, with an iron wire which he heated to a white heat and then fused in contact with moistened alumina, the operation being performed in an atmosphere of hydrogen. The iron, upon analysis, was found to be alloyed with aluminum.

Bunsen in Germany, and Deville in France, in 1854 each electrolyzed the double chloride of aluminum and sodium. Le Chatelier obtained English patent No. 1214 in 1861, and Monckton, in 1862, English patent No. 264 for the reduction of aluminum by

aid of electricity. In fact, Richards says that the Monckton patent "proposes to pass an electric current through a reduction chamber, and in this way to raise the temperature to such a point that alumina will be reduced by the carbon present," showing not only that the use of electricity for reducing aluminum was old, but that the idea of the electric furnace dates back to 1862.

The newer pure aluminum processes using electricity, of Hall, Heroult and the Bernard Brothers, with the help of Minet; together with the alloy processes of the Cowles Brothers and of Heroult, are the only ones that have been of late worked upon a commercial scale.

Besides these, there have been a host of other electrical attempts and experiments for the manufacture, since the success of some of the other companies using electricity became known.

THE HALL PROCESS OF ALUMINUM PRODUCTION.

The Hall process consists in electrolyzing alumina dissolved in a fused mixture of fluorides of aluminum and sodium, or of fluorides of aluminum and potassium. In fact, Mr. Hall mentions in his letters-patent No. 400,667 a fused bath in which the alumina is dissolved in the fluoride of aluminum, together with the fluoride of any metal more electro-positive than aluminum.

As the Pittsburg Reduction Company uses the process, it places the mixture of fluoride salts in a row of carbon-lined iron tanks placed in series. The pots, together with their carbon linings and the reduced metal in the bottom of the pots, become the negative electrodes or cathodes. The positive electrodes or anodes are a series of carbon cylinders, 3 inches in diameter, attached by $\frac{3}{8}$-inch copper rods to the copper conductors by the aid of suitable clamps. The current of 5000 amperes and 50 volts is turned on, and the mixture is melted by the heat developed in the passage of the current through the fluoride mixture. In less than two hours' time the mixture becomes fluid, and the alumina is added. The electrolyte then becomes a much better conductor, "the resistance of the pot" falls so as to require only about 8 volts, and the operation of electrolysis commences. The alumina in solution, or, as some claim, the fluoride of aluminum is decomposed; the metal being heavier than the electrolyte, sinks to the bottom of the pot, and the oxygen goes to the positive carbon electrode, uniting with a portion of the carbon and escaping as carbonic acid gas; or, as is maintained by some, the aluminum of the fluoride of aluminum is deposited, and the fluorine attacks the dissolved oxide, reforming fluoride of aluminum, and thus main-

taining the integrity of the original electrolyte bath, the oxygen going off, as in the other case, at the positive electrode.

DETAILS AND ADVANTAGES OF THE HALL PROCESS.

In the practice of the Hall process the heat is retained in the molten bath by a covering of finely powdered carbon on the surface of the molten mixture. On top of this carbon raft the powdered alumina is placed, and when the voltameter attached to each pot shows a rising resistance, the pot-tender stirs in more heated ore from the surface of the pot. The carbon soon comes to the surface, when a fresh supply of ore is placed on it. The feeding is thus easily made continuous, and, as the electrolyte remains constant it requires only the removal of the metal to make the entire operation continuous. The pots are run for months at a time. The following are the chief advantages of the continuity ot the process:

1. Purity of the Metal. After the first run of metal is cast, carrying with it all the iron and silica, or rather the reducible impurities of the electrolyte, the only other sources of impurity are in the pure alumina added and in the ash of the positive carbon electrodes, which are worn away. The weight of carbon burned away is a little less than that of the metal produced.

2. Saving of Material. The loss of metal and ore in a finely-divided state in the bath, which occurs when a shut-down is required, is avoided. To be sure, this lost metal can be largely regained by melting again; but in melting down, the metal in a finely-divided state is found to be almost entirely redissolved. As continuously carried on, the loss of metal is practically nothing, every particle being reduced; undoubtedly it is often reduced more than once by being redissolved before settling through the bath to the metal below, when the ore gets out of the electrolyte and it becomes acid. At the same time, as there is no slag or other waste product, solid or liquid, evolved, and as the gases can carry off none of the aluminum, all of the aluminum in the ore added, is finally brought out in ingot metal, a result that is seldom experienced in the reduction of other metals from their ores.

3. Economy. The original heat of the electrolyte is constantly maintained, and the only supplies needed are the constant electric current, the alumina ore and fresh carbon electrodes to replace those worn out, with only occasional additions of fresh electrolyte to replace the small loss of that taken out with the ingot metal or that which has become decomposed by the workmen carelessly letting the pots get out of ore. This decomposition

of the electrolyte means an infusible "cake," as the workmen call it, settling to the bottom of the pot and filling it up. When the pots are not skilfully run, or more easily decomposing electrolyte mixtures are used, this accumulation shortens the run of the pot, and also decreases the output. In the regular practice of the Pittsburg Reduction Company there is practically no decomposition of the electrolyte, and a pound of aluminum is made with an expenditure of about 22 electrical horse-power per hour.

This electrical energy, expended in heat, is not very costly, as water-power may be used at a cost of $12 per horse-power per annum. Allowing 25 per cent. for loss in converting mechanical into electrical energy, and supposing 75 per cent. of the remaining energy to be converted into heat, Professor Richards has calculated the heat generated by one horse-power during one year as 8,400,000 heat units.

The Hall process can be successfully carried on entirely independently of carbon, using a thick iron or copper tank, and either iron or copper electrodes. The deposition of the metal is nearly as large as with the use of carbon electrodes; but the metal is, of course, alloyed with the copper or iron worn away from the positive electrode.

The Pittsburg Reduction Company has made, by this process, alloys of aluminum with iron and copper similar in character to the alloys produced by the Cowles and Heroult alloy processes.

THE HEROULT AND MINET PROCESSES.

Almost at the same time that Hall invented his process for manufacture of aluminum, in the early part of 1886 (his first patent application, dating July 9, 1886), M. Pierre Heroult commenced operations, and afterwards took out English patent No. 7426, of 1887, fluxing alumina with cryolite. The bath was put into a graphite crucible, which served as a negative electrode, and this was put inside a larger crucible, the space between the two being filled with graphite, and the carbon positive electrode being immersed in the fused bath. The ideas of M. Heroult and Mr. Hall were very nearly identical at the start. M. Heroult attempted to obtain an American patent, and was declared in interference with Hall; and, after the testimony as to dates of invention and of application for patents had been taken, M. Heroult withdrew in favor of Mr. Hall. This process was practically abandoned for a while by M. Heroult in favor of his very successful alloy process of electrolyzing and reducing molten alumina; but, since 1889, when a growing demand sprang up for pure aluminum, and the success

of the Hall process became known, two concerns have begun working under the same principles—the Aluminum Industrie Actien Gesellschaft, at Neuhausen, Switzerland, and the Socié é Electro-Métallurgique de France, at Froges (Isère) in France.

The process, commonly called "the Minet process," as developed and used at the works of the Bernard Brothers, at Creil, Oise, France, consists in electrolyzing a mixture of sodium chloride with aluminum fluoride, or with double fluoride of sodium and aluminum, their English patent dating July 18, 1887, No. 10,057. This company has been doing successful work and is now putting on the market aluminum of good quality. Thus it will be seen that there have developed apparently three separate electrolytic processes for the manufacture of pure aluminum at about the same time, and all of them are working on about the same lines. These, together with the Cowles and Heroult processes for the manufacture of aluminum alloys, have, for the past two years, distanced all competitors manufacturing by the aid of metallic sodium, and are to-day in the possession of the aluminum market of the world.

THEORETICAL COST OF MANUFACTURE BY ELECTROLYSIS.

Theoretically, the cost price, calculated by Mr. Hunt, of the manufacture of aluminum by direct electrolysis has already been brought down very low as compared with the cost of the more complicated processes of a few years ago. The cost per pound is about as follows:

2 lbs. of alumina (Al_2O_3 contains 52.94 per cent. Al_2) at 3 cts.	$0.06
1 lb. of carbon electrode at 2 cts.	.02
Chemicals, carbon dust and pots	.01
22 E. H.P. exerted one hour, water power being used	.05
Labor and superintendence	.03
General expense, interest and repairs	.03
Total	$0.20

The works of the Pittsburg Reduction Company were built to practice the Hall process, and began in a comparatively small way in Pittsburg in 1888.

This plant was increased by the building of works at Niagara Falls to utilize the power of the great plant of the Niagara Falls Power Company which are now in very successful operation using thousands of horse-power.

Another new plant, operated by steam, has recently been built at New Kensington, near Pittsburg, and still another is being built below Niagara Falls, to utilize power from the old surface canal.

Besides these, large works are in operation in England, France and Switzerland.

With all these immense plants in operation we may expect to see the price of aluminum nearly or quite reach the theoretical cost of 20 cents per pound, calculated by Mr. Hunt.

DISCUSSION.

H. G. Field.—I have just returned from a meeting of the American Street Railway Association at Niagara Falls. While there, I learned from Mr. Candee, one of the leading manufacturers of insulated wires, that he has under advisement at the present time the possible use of aluminum to replace copper as an electrical conductor.

There are numerous objections to be overcome, both as to structural considerations and as to the cost of insulating and handling.

The electrical conductivity of aluminum, in equal lengths and the same weights, is approximately twice that of copper; but, for the same cross-section, the specific resistance of aluminum is nearly double that of copper.

The additional diameter of aluminum over that of copper for the same conductivity, will increase the cost of insulation for the same conductivity. The larger diameter also means more surface for the leakage of current, and the insulation resistance will be less, unless the thickness of the insulation is increased. An increased thickness of insulation means increased electrostatic capacity as well as greater cost.

Moreover, it is found that if aluminum wires, of ordinary size, such as are used for electrical conductors, are bent once through an angle of 90° and back, they will break, whereas ordinary commercial copper conductors will stand from 15 to 20 of these same bendings before breaking.

These are all objectionable features, and it would therefore seem doubtful whether aluminum conductors will prove merchantable. If such conductors are to be made commercially valuable it seems that the method of protection must necessarily be reduced to that of a mechanical covering, such as a braid or a series of braids treated with a bituminous composition to make it weatherproof, and also to assist in mechanical strength. This, however, will limit the use of aluminum for electrical conductors to special applications and prevent it from coming into general competition with copper.

As particularly applicable to aluminum in the conduction of

electrical currents I observed, at the Niagara Falls Power Company's works, 500 conductors about 000 B. & S. gauge, used for carrying the current from the buss-bars in the dynamo room up through the penstock shaft into the factory above, a distance of something over 200 feet. These conductors were not insulated, except by a coating of paint over each one. Each set, of 250 each, is run in a separate wooden trough up through this shaft. This is the only insulation provided. These conductors are riveted to the copper buss-bars at the terminals. The dynamos connected to these buss-bars have a normal capacity of 4000 to 6000 horse-power.

I would state also that the Westinghouse Manufacturing Company is now using fuses of aluminum for switchboard work. These fuses are long and made of thin sheet metal, with reduced sections at the center. I brought one with me from the Pittsburg Reduction Company, and will pass it around for examination. These are found to be accurate in rating, and mechanically serviceable, and in these respects superior to the common soft metal fuses.

ALEX. DOW.—Mr. Field has noted two uses to which aluminum has been put in electrical engineering. The fuses made of aluminum ribbon have been on the market for a little time, and have been in use in Detroit for about a year past on high-tension alternating circuits. The tendency, on these circuits, is to avoid the use of fuses made of alloys, which are less certain in their action than fuses made of pure metal. For transformer fuses a wire of aluminum is sometimes used, but the preference there appears to be for fine copper wire in specially designed holders. For larger currents, such as pass through feeder fuses, the aluminum ribbon is very satisfactory, both mechanically and electrically. It is not injured by being pinched under the terminal screws, and it fuses at the predetermined current, but is not altered by being traversed by a less current. Fuses made of alloys, if heated and cooled many times, are apt to melt at a less current than their rating; so that one does not know what to expect of an alloy fuse which has been in service for some time.

As to the use of aluminum for electrical conductors: the instance to which Mr. Field has referred, namely, the vertical conductors which are led up the cliff near the "Maid of the Mist" landing at Niagara, is, I believe, a solitary instance. The objection to aluminum as a conductor, in competition with copper, is that a greater cross-section is required for equal conductivity, and the greater cross-section means a greater periphery. As almost all

electrical conductors are of circular cross-section, there is no opportunity to vary the relation between periphery and area of cross-section. All electrical conductors must be insulated. When the conductors are used within buildings or laid underground the insulation is in the form of a continuous covering of india-rubber or of some analogous dielectric. The cost of this continuous covering is a very large proportion of the total cost of the conductor; and its quantity is proportional to the total surface of the conductor, and therefore to the periphery. It results that the cost of insulation, on an aluminum conductor of a given capacity, will be much in excess of that on an equal copper conductor.

When conductors are not continuously insulated but are intended to be hung on poles outdoors, the cost of a covering does not enter into the cost of the line; but the objection to aluminum takes the same form, namely, too large a periphery for a given conductivity. It is seldom that the vertical stress, due to the weight of conductors, is of importance in the estimate of the expense of a telegraph, telephone or power transmission line erected in the common American fashion. The practice is to use poles whose strength, in a vertical line, is greatly in excess of that necessary to carry the weight of the wires. But in all parts of the United States a most important factor is the stress along an approximately horizontal line due to wind pressure. This stress is obviously proportional to the projected area normal to the line of stress—in other words, to the diameters of the wires strung on the pole line. The increased diameter of aluminum wire would require a much greater transverse strength of poles or much heavier bracing against wind pressure. In the Northern States another factor which must be considered and which indeed is the factor responsible for most of the extensive wrecks of telegraph and telephone lines, is the weight of the sleet or wet snow which has to be supported by the wires when certain atmospheric conditions prevail. It is nothing uncommon for a wire to be loaded with a continuous icy covering having a thickness of $\frac{1}{8}$ to 3-16 of an inch, whose weight is many times that of the metal in the small conductors used in telegraph and telephone service. As pointed out in connection with continuous insulation of conductors, the quantity of this covering, and therefore its weight, is proportional to the periphery of the conductor. I should expect that a pole line having aluminum conductors equal electrically to those in use by the long distance telephone company would be utterly wrecked at least once a year if erected in the lake regions, unless there were used about three times the numbers of poles, struts and stays that are customary for the existing copper conductor lines.

For the moving parts of galvanometers and other electrical instruments where lightness is of importance, aluminum has come into use, but the quantity required for these purposes is a trifle. In some galvanic cells, aluminum has been used as an element. In what might be called electrical hardware it has proved itself as useful as in similar lines of manufacture. But I think it is fair to say to-day that the new metal has been of much less value to electrical engineering than electrical engineering has been to the new metal, and that this condition of affairs is likely to continue. Mr. Smith has shown that electrical processes of production are the only processes by which aluminum is now being prepared for the market, while, as I have pointed out, the electrical uses of aluminum are so far of little importance.

W. J. Keep.—The influence of aluminum in cast iron was determined during a series of experiments which I made in 1887, and was the subject of a paper read before the American Association for the Advancement of Science in 1888. It was discovered that aluminum in cast iron changed combined carbon into graphite, thereby making white iron gray, hard iron soft and brittle iron tough, and that it reduced shrinkage. These experiments were made at the request of the Messrs. Cowles, who had just begun to make an alloy of 10 per cent. aluminum, 5 per cent. silicon and 85 per cent. iron, and wished to know if a small quantity added to cast iron would not materially strengthen it. After the results of these experiments were published it was suggested that it was the silicon in the Cowles alloy, and not the aluminum, that produced the results. I obtained enough pure aluminum from Germany to duplicate the experiments, and found that the action of aluminum was the same as that of silicon, but that only one-third as much aluminum was needed to produce a given result. The result of these experiments was given to the American Institute of Mining Engineers, and is found in their Transactions of 1889, vol. xviii.

In this paper I stated that there were practical difficulties which prevented the use of aluminum in cast iron, and that increasing silicon, which could be purchased at pig iron prices, would do all that aluminum could do. I stated that the only iron that could be benefited by either was that which was deficient in silicon, and that additions to iron already soft and gray would make it weaker. In making malleable iron castings, the effort is to get most of the carbon in the combined state before the molds are filled, and an addition of aluminum changes it back to graphite.

While these experiments were in progress, Captain Hunt, of Pittsburg succeeded in making pure aluminum, and sent me enough to allow of transverse tests and of a comparison with other metals. Previous to this time the general impression was that aluminum was as strong as steel, while it was only one-third as heavy. These tests showed that it was about as strong as brass, bulk for bulk.

These investigations were reported in another paper in the volume referred to.

Regarding the influence of aluminum in wrought iron and in steel castings, I made the following experiments with the metal received from Captain Hunt: The Detroit Steel and Spring Works volunteered to melt 80 pounds of wrought iron, and I prepared five molds for test bars. A mold was to hold 13 pounds. I provided four long sticks of carbon, to the ends of which were attached, respectively 3, 7, 5 and 3 ounces of aluminum. After being in the furnace six hours, the pot was drawn and the first mold was filled. The pot was set down on the iron floor, and I was told that the metal was too thick to do anything with, but, as it could do no harm, the 3 ounces of aluminum was stirred, and, to the surprise of all, the metal was more fluid than before. After filling the second mold, the 7 ounces was stirred in and another mold poured, and so on. Eighteen ounces of aluminum was melted and four carbon sticks of one inch diameter were heated white, and the pot set on the cold floor five times, and yet the metal remaining was whiter and more fluid than when taken from the furnace, and when poured on the floor spread out in a slab $\frac{1}{2}$ inch thick.

This series of test bars was made with 1.50 per cent. carbon steel. It was thus proved that aluminum lowered the melting point of wrought iron and made it very much more fluid. The molds proved too rigid, and each test bar cracked. This made it necessary for me to remelt them in my own crucible furnace. While I could not melt wrought iron I could remelt that which had been melted at the steel works. The metal containing additions of aluminum melted readily and I got good bars. This remelting settled the question of lowering the melting point and proved that the aluminum remained in the metal. The test bars from the melted wrought iron had blowholes extending through their entire length, but even so little as 1-10 of 1 per cent. of aluminum made perfectly solid castings. Very many makers of steel castings use aluminum, and others use silicon, to prevent blowholes and to increase fluidity, but too much aluminum so

increases the size of the grain as to make the casting weak. In the experiments referred to, each addition of aluminum made the casting harder, stiffer and stronger, but after reaching 3 per cent. the coarse crystallization so weakened the alloy that with 10 per cent. it was weaker than pure aluminum.

With 50 per cent., the test bars fell apart of their own weight, and, after being left 3 months, they had fallen into a fine powder.

The paper on "Aluminum in Wrought Iron and Steel Castings" is also in vol. xviii. Taken collectively, so far as I know, these are the only tests that have been made public regarding the influence of aluminum in iron.

The addition of steel scrap to cast iron, to produce semi-steel castings, and the use of aluminum to make it fluid and free from blowholes is a subject of general interest. The addition of about 20 per cent. of wrought scrap to cast iron generally increases the strength from 15 to 25 per cent., probably on account of a mechanical mixture of the pure iron with the cast iron, and not from the change in chemical composition, because cast iron made in the blast furnaces and of the same composition is not necessarily strong.

A. Geo. Mattsson.—Within the last few years a higher grade of cast iron, popularly called "semi-steel," has found its way into the foundry among some of the marine engine builders on the Pacific coast, as well as on the great lakes.

In our own city the Riverside Iron Works adopted this metal in 1893, and the Dry Dock Engine Works in 1895, both firms having purchased the manufacturing right under the McDowell patent.

This mixture consists of ordinary cast iron and scrap steel plate, melted together in the cupola, and in the bottom of the ladle is added a very small quantity of aluminum alloy, consisting of 80 parts of iron and 20 parts of aluminum.

The usual transverse strength is 3000 pounds, measured on bars 1 inch square and 12 inches between supports. The strength can easily be increased to 3500 pounds by adding more steel scrap.

The 3000 pounds metal is but little harder to work than ordinary good cast iron, which we have found to possess a transverse strength of 2000 to 2500 pounds.

The 3500 pounds metal is somewhat harder on the tools than cast iron, but not hard enough to cause difficulties of any kind.

The price is but little greater than that of cast iron, as the steel scrap can be bought cheaper than the former. In fact, consider-

ing the increased strength, semi-steel certainly does not cost any more than cast iron. We use it wherever a reliable and strong casting is wanted.

The cross-section of semi-steel is very close grained and uniform, and presents an excellent wearing surface when finished.

A few efforts have been made to produce castings of aluminum bronze at the foundry of the Riverside Iron Works, principally for small propellers where any reduction in thickness of the blades is very appreciable, but owing to the difficulty of properly mixing aluminum with the copper, the former, on account of its lightness, tending to float, the attempts have met with but little success. The only way to make sure of a sound casting is to remelt the mixture two or three times.

At the Dry Dock Engine Works a copper, tin and aluminum alloy of the following proportions is used regularly to produce a strong and free-running bronze: 7 pounds of copper, 1 pound of tin; to each 75 pounds add 1 ounce of aluminum.

As a conclusion we may safely say, however, that the permissible amount of aluminum, as an alloy either with cast iron or bronze, is very small indeed.

Jesse M. Smith.—Among other properties of aluminum may be mentioned one of considerable importance; namely, the galvanic action which is set up when it is brought into contact with other metals in the presence of moisture, particularly, when the moisture is either acid or saline.

Of the common metals, aluminum is the most electro-positive; and when it is brought into contact with any of the other common metals a galvanic battery is formed.

As in such a battery it is the electro-positive metal which is attacked or eaten away first and most rapidly, it follows that aluminum always goes first and fastest whenever a galvanic action is set up.

The strength of this destroying galvanic action increases with the different common metals in the following order: Manganese, zinc, iron, lead, tin, copper, silver, gold, platinum, carbon.

Care should be taken, therefore, in structures made of different metals exposed to moisture, such as boats in salt water, that aluminum does not come in contact with carbon, copper, tin or lead; but preferably, if necessary, with zinc or iron.

Aluminum is distinctly porous, particularly in the form of castings, and it cannot be relied upon to retain liquids or gases under a pressure exceeding 100 pounds per square inch.

The comparatively low melting point of aluminum, being

about one-half that of mild steel, and the fact that it has a "critical point" at between 300° and 400° F., at which it loses its strength very rapidly, precludes its use for steam boilers.

A peculiar use of this metal, which I understand has already become quite extensive, is in making lithograph plates to be used in place of the cumbersome and expensive stones that are imported from Germany. It is said that finer and better work can be done on the aluminum plates than can be done on stone.

The price of aluminum is practically equal to that of brass, bulk for bulk; and it is cheaper than copper, section for section.

It is said that between 600 and 700 tons of aluminum were used in 1896, and that double that amount will be used this year.

HYDRAULIC RAMS.

By J. Richards, Member of the Technical Society of the Pacific Coast.

[Read before the Society, September 3, 1897.*]

The paper I will have the honor to present before the Society this evening comprehends but a part of the subject-matter of a more pretentious essay on the subject of "Impulsive Hydraulic Apparatus," that has not been completed, for a reason only too obvious to nearly all the busy members of societies of this kind—the want of time.

The paper was incautiously mentioned to one of the Executive Committee and to the Secretary, who has called it up in its unfinished state, and who are, therefore, in a degree responsible for what it lacks in completeness.

The name "impulsive hydraulic apparatus" is borrowed from the classification of the British Patent Office. It covers a class of machinery and devices in which the implements we call "hydraulic rams" form but one division.

This general title would have rendered the present paper pretentious, so it has been called "Hydraulic Rams," and will, as far as possible, be confined to these ridiculously named implements.

Before coming to the subject of hydraulic rams, it will be proper to mention the exhaustive investigations in the action of fluids set on foot in France at the beginning of this century, and which even at this time constitute the main source of information on this subject. The names of Fourneyron, Jonval, Bourdon, Girard, Morin, Montgolfier and others are known all over the world in connection with hydraulic and other fluid apparatus.

The investigations in hydraulic apparatus were no doubt instigated in some degree by Montgolfier's invention of the hydraulic ram, about 120 years ago, and may be said to have culminated in the invention of Giffard's induction devices, the injector and ejector, for elastic and inelastic fluids, introduced about forty years ago.

Since that time progress in fluid apparatus has been more widely diffused, producing in this country the centripetal turbine and tangential water wheels, in England the Parsons, and in Sweden the De Laval steam turbines, with much else of an important and interesting nature.

*Manuscript received January 13, 1898.—Secretary, Ass'n of Eng. Socs.

Hydraulic rams, if we consider only what may be called the commercial type of these implements, have remained without much change for a century past, or since their invention by Montgolfier, but there have been some important inventions made in impulsive apparatus that are commonly classed under this name, as, for example, the air-compressing apparatus invented and applied by Sommellier at the construction of the Mount Cenis Tunnel and the hydraulic engines of Mr. Pearsall, brought out in England about 1885; also various other special machines, for forcing and raising water by impulsive action, that have not become known as a manufacture.

This long period of use and experiment with common hydraulic rams has not, however, as in most, or, indeed, nearly all, other cases, led to an evolution in their adaptation and construc-

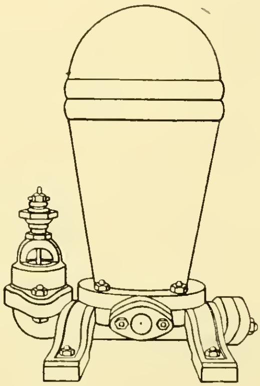


FIG. 1.

tion. As before remarked, they have remained very nearly in their original form; and, in this country, instead of keeping pace with other hydraulic apparatus, have degenerated into a kind of staple manufacture, like hardware, with a continued effort toward cheapness, until we are distinctly behind European makers in design, efficiency, durability, certainty of action, and especially in devices for use against high pressures.

Fig. 1 shows a type of the hydraulic rams made in this country, and very closely followed by several of the principal makers. I need not point out that it is not a design that commends itself. It shows a struggle for cheapness and a want of harmony, especially marked in contrast with European practice.

In illustration of this, I have prepared outline drawings from some examples by a well-known maker in England, Mr. John Blake, of Accrington, who makes a great variety of hydraulic

rams to raise water up to 800 feet or even 1500 feet by compounding; raising either the water employed as power, or other water when required. These rams can be arranged to start and stop automatically.

Figs. 2 to 6 show side elevations of hydraulic rams by this maker. The prices demanded for these are about five times that of the common trade rams sold in this country.

This matter of price I mention not wholly as a disparagement of the practice here; because the rams, such as are shown in Fig. 1, perform under fair efficiency for low heads or pressures, and be-

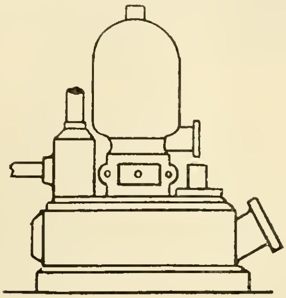


FIG. 2.

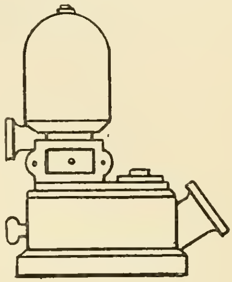


FIG. 3.

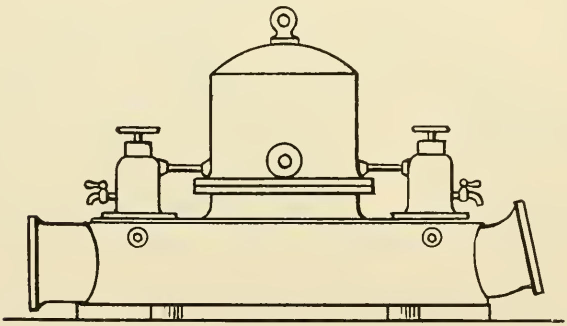


FIG. 4.

come available in many cases for private use when better and more expensive apparatus could not be afforded. Still, this does not excuse our position in the art as a whole.

In France, Germany and Switzerland, hydraulic rams are made of less weight and strength than in the English examples shown, but are commonly far superior to those made in this country. I am not able to furnish drawings of various European rams without extending the graphic part of this paper beyond the limit of its importance. Such drawings would only disclose modifications of arrangement and proportions, the mode of operation being substantially the same throughout in what has been called the commercial types.

A hydraulic ram consists essentially of supply and delivery pipes, waste and check valves, a main chamber and an air vessel. The mode of operation is to permit a flow in the supply pipe by an escape of water, and then, suddenly checking this flow, to direct the energy or momentum of the water in the supply pipe to driving water through a check valve into the air vessel and thence through a delivery pipe.

The theoretical and computable elements involved in the action of hydraulic rams are simple, so far as the principal forces are concerned, but there are conditions and phenomena in such action that have, in the case of the small rams at least, confined nearly all rules to observed instead of computed results.

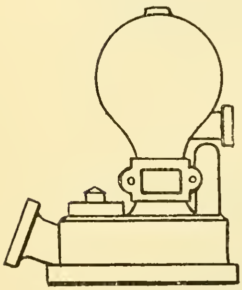


FIG. 5.

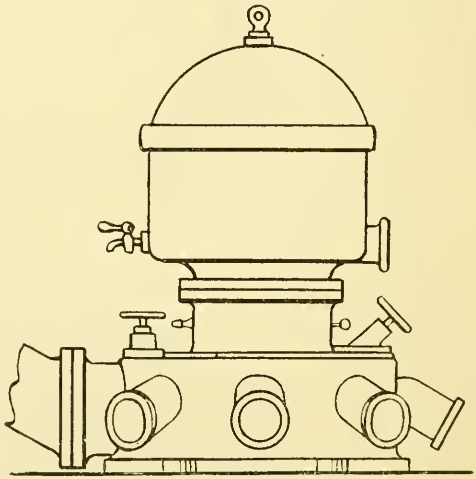


FIG. 6.

Molesworth, in his engineering pocket-book, says, of hydraulic rams: "One-seventh of the water can be raised about four times the head of the supply; or, one-fourteenth of the water to eight times the head; or, one-twenty-fourth to sixteen times the head, and so on."

He also provides tables in which the height to which the water is raised, divided by the supply head, gives results as follows:

Fourteen to one efficiency, 75 per cent.

Fifteen to one efficiency, 28 per cent.

Twenty-five to one efficiency, 10 per cent.

If, by efficiency is meant the proportion of energy utilized, I need not say that the two statements are inconsistent, or that, if the constructive features of a machine are adapted to the head

or pressure, the efficiency should be uniform, or nearly so, for all heads within common practice, with a limitation that no literature on the subject has dealt with, so far as I know,—that is, the resistance offered by the inertia of the water over and resting on the check valves. This matter will be dealt with further on.

On this subject of the literature of the hydraulic rams I will venture the statement that it is scant, of bad quality, and has never lent much aid to those who are practically engaged in making such implements.

For example, Molesworth gives as a proper length for the supply pipes 2.8 times the fall. Other authorities increase this to four and some fraction. The value of these rules will be apparent when we consider the fact that there are, in successful operation,

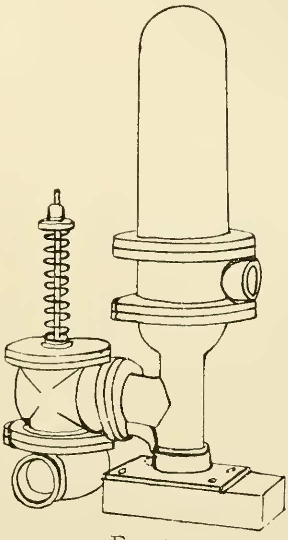


Fig. 7.

hydraulic rams with supply pipes 25 times the head in length, and that this feature is not a matter of much concern to those who make and erect such apparatus.

At Rockford, in Illinois, there has been in operation, for more than a year past, a large hydraulic ram, shown in Fig. 7, having a supply pipe 2000 feet long, under a head of about 80 feet. It was designed and made by Mr. D. W. Mead, of that city, for the purpose of municipal supply. The period of its strokes is from 15 to 20 seconds. The drawing was made from a photograph of the apparatus, furnished to me by Mr. Mead, with whom I am personally acquainted. It may be observed that the whole structure is pieced up of common service pipe.

I do not claim that a ram will operate as well with a very long supply pipe. Indeed, I have increased their efficiency by shortening the pipes; but this, I imagine, depends on the construction of the valves more than on any inherent condition of operating, such as is indicated by the rules before referred to.

So far as I am aware, there has been no careful attempt to analyze the various forces involved in the operation of common hydraulic rams, except that of the momentum of the driving water at assumed velocities, nor can we reasonably expect much more. There is the force required to open the waste valves that are commonly assumed to open by their gravity, exceeding the pressure of the supply water that holds them shut. This was, no doubt, one of the conditions originally laid down by Montgolfier. It is a logical and reasonable inference; but it is also a myth, because the weight of a waste valve, while determining to some extent the period of its closing, has in practice but little to do with its opening. This latter operation depends upon what some one, without regard to scientific nomenclature, has happily termed "regurgitation," an excellent name for a thing one does not understand. In this case it means a kind of rebounding action of the water, supposedly inelastic, such as would occur with a gas or elastic fluid, and lies wholly outside of any known law in hydraulics.

My own observations of this matter, confirmed by those of Mr. C. I. Hall, a member of this Society, lead to the opinion that this forcible and rhythmic action of the waste valves, the most obscure of all in the operation of hydraulic rams, is a result of elastic resistances caused by the closing of the check valve, the yielding of the pipes, the water chamber and the air vessels, with perhaps some air in the water, which, all combined, set up a resilient action. This is mainly conjecture, and is so presented. I may mention here that in some recent experiments made by Mr. Hall, it was found that the slightest amount of air introduced into the driving pipe would stop the action of the ram, cushioning the water so that the escape valve would not open.

Another source of indeterminateness is that the velocity of flow in the supply pipes, which is commonly computed as a product of the head, is not so in fact. The rule of acceleration applies, no doubt, but no one attempts to attain a maximum flow, for fear of exceeding the synchronic period of the valves' action, and by the limitation thus imposed the velocity does not, in my opinion, reach two-thirds of the theoretical flow, perhaps is less in most cases. It is a matter regulated by the weight and range of the

waste valve, and, like all other adjustments of a hydraulic ram, is accomplished by sight, sound and inference.

I have had under almost daily observance, for five years past, a small American hydraulic ram, supplied from and discharging into tanks, so that the operation, under all possible adjustments, and its efficiency, were continually apparent, and I must confess that, after hundreds of alterations and adjustments, the only clue to the efficiency of performance is by sight and sound. The number of strokes which gives the best result, under what I conceive to be proper adjustment of the valves, is 70 per minute. The supply pipe is 50 feet long, the head is about 6 to 1, and the efficiency from 50 to 65 per cent., according to the state of the pipes, which become encrusted with some mineral deposit. These proportions and numbers of stroke indicate, as I now remember, a maximum velocity in the supply pipe not exceeding 60 per cent. of the theoretical during the period of maximum escape.

Reverting again to "regurgitation," or the opening of the waste valves; as before remarked, the old theory of the matter taught in works of natural philosophy was that the valves opened because their weight exceeded the static pressure of the head in the supply pipe. This is now the common opinion of this matter, but is quite erroneous. The weight of the valve has but little to do with its opening; but a great deal to do with its closing; also, if not carefully adjusted, in respect to the head of the supply water and the range of the valve, it becomes a cause of serious loss.

A proof that the weight of the waste valves has little to do with their opening movement is that the rams of commerce are usually made with uniform valves for all heads and without provision to increase or diminish their weight. This is, however, a mistake. It is based on the assumption that the periods of impulse, or the strokes, can be regulated by the range of the valves, which is true within the common limits of length for supply pipes, but it exposes the valve to violent concussion in the case of high heads and otherwise is bad practice. The weight and range of a waste valve require specific adjustment, relatively, for reasons that will be given later on, and any other provision must be set down as an expedient for cheap production, or as due to the inability, on the part of those who purchase rams, to adjust them.

Perhaps the latter is a valid and sufficient reason for omitting so obvious a requirement as a variable weight for waste valves, because it is seldom that one is found operating under proper adjustment, and under these circumstances the result would be much the same, no matter what means were provided by a maker

to meet the varied conditions of use. Such adjustment is a problem of sight, sound and experiment, and is consequently a mystery to almost every one except an expert.

The losses in hydraulic rams, as before noted, arise from water friction, from resistance of the check valves and from concussion or shock, but mainly by the escape of water after the waste valves begin to close. This latter, to which the inventions of Sommellier, Pearsall and others have been especially directed, is estimated at 15 to 25 per cent., depending upon adjustment, the character of the waste valves and their range.

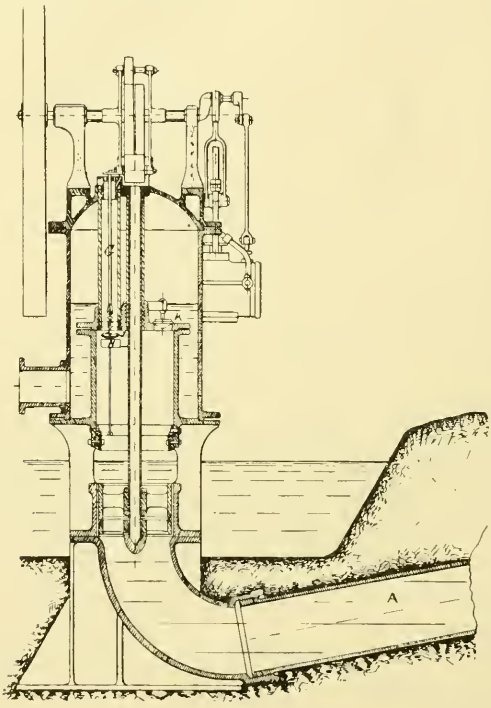


Fig. 8.

It is obvious that, as soon as the waste valves begin to close, there is resistance to the supply water; and, from then on until the check valve opens, no useful work is performed, and all water that escapes during this time is wasted. This is a matter by no means simple or obvious, and it is not commonly known, even by makers of hydraulic rams, so it has not been provided for to such an extent as is possible.

In the Pearsall hydraulic rams, or engines, as he calls them, shown in Fig. 8, this loss is nearly eliminated by providing a large vertical chamber, into which the supply water is driven while the

waste valve is closing, so that the momentum of the supply water is resisted only by air that is entrapped in this chamber at each stroke. Hence the energy is gradually applied without concussion, and is utilized in an economical way for useful work. A diagram of pressure in this antechamber is shown in Fig. 9, which indicates a very perfect action.

The waste valve of Pearsall's machine is operated by a small engine, driven by the air entrapped and compressed in the chamber over the waste valve, the water falling out of this chamber and permitting it to fill with air each time the waste valve opens and before the flow in the supply pipe begins.

The action of the Pearsall engine, while it is strictly of the nature of impulse, is so distinct from that of the common hydraulic rams that it cannot be included under this head. The action is an interesting study, and there are many original features. Still,

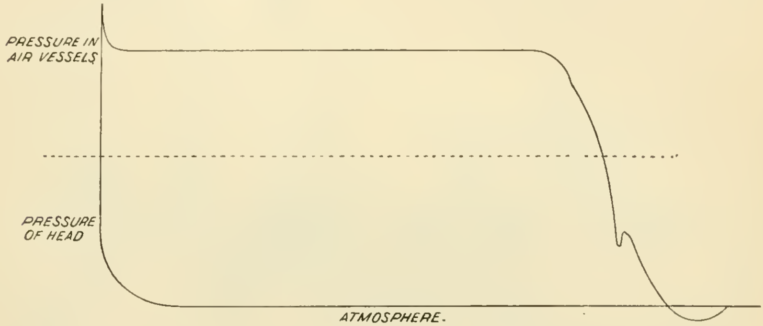


Fig. 9.

it is, in general, an extension, as we may say, of the Sommellier machines, in that there is no lost energy of the driving water in closing or during the closing of the waste valves. Sommellier accomplished the same thing with a series of valves that closed successively by the effect of the water rising in the compression chamber or air vessel. The limits of this paper will not warrant the inclusion of drawings of these machines. They can be examined in various technical serials and in books.

This method of operating is not applicable to small machines, and has not, I believe, been employed in any case where the supply pipes were smaller than 12 inches bore.

I will next revert to my own connection with this subject of hydraulic rams, and describe some practice of interest that has had no previous publicity, except in an article prepared for the *Engineering and Mining Journal*, and published in the issue of August 25, 1896, that included drawings of several modifications made here in San Francisco eight years before.

In 1886, without any reference to Mr. Pearsall's experiments and without knowing much of the nature and objects of other impulsive acting machines, I suggested to the late Mr. W. T. Garrett, of this city, that we make some hydraulic rams that would operate without shock or violent closing of the waste valves, and in 1888 a number of experiments were made at the works of W. T. Garrett & Co., Fifth and Brannan streets, in this city.

Proceeding in this matter, as we supposed, in a systematic way, the first proposition laid down was to employ waste valves that passed freely through their seats or without contact in closing. This feature was adhered to throughout, and its object was based on the assumption that the concussive action was destructive and undesirable, and was a product of the range of the valve and its

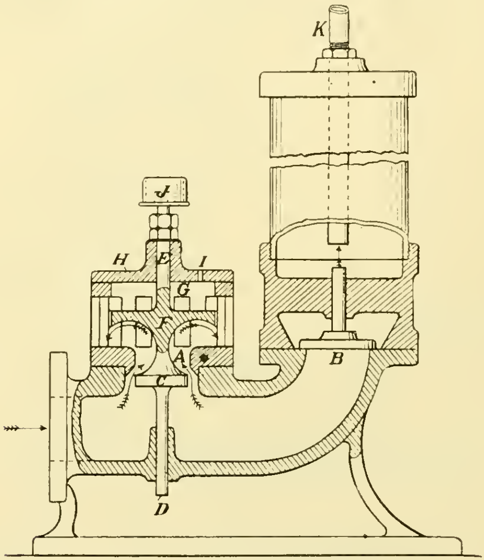


Fig. 10.

diameter or capacity, and that a better result could be attained by cushioning the waste valves.

A second proposition laid down was that a better result could be obtained by closing the waste valves by reaction of the escaping water than by its impingement, or current, acting under or around the valves. These were wide departures from common practice, but were adhered to throughout, as can be seen in the drawings Figs. 10 to 15, now to be referred to.

In Fig. 10 A is the valve seat, B the check valve, C the escape valve, D and E valve stems, F a curved reaction shield, also forming an air piston that fits the shallow chamber G above, H a

removable cover, I an air vent, commonly supplied with a cock, J a weight to assist the waste valve in opening, and K the discharge pipe. The valve C, as may be seen, passes freely through its seat.

In Fig. 11, the pneumatic piston or cushion is omitted, and the escape valve is balanced by a piston C at the bottom, that slides in a cage or guide D. The escape valve, in closing, had only its weight to produce concussion, and the blow was taken by a leather washer at G. The valve closed instantly by reaction from the curved shield A, and the operation was complete until friction or obstruction interfered with the motion of the piston C. The check valve was bad, as it was in Fig. 10, because of its wide, flat seat and the difference of area between the top and the bottom.

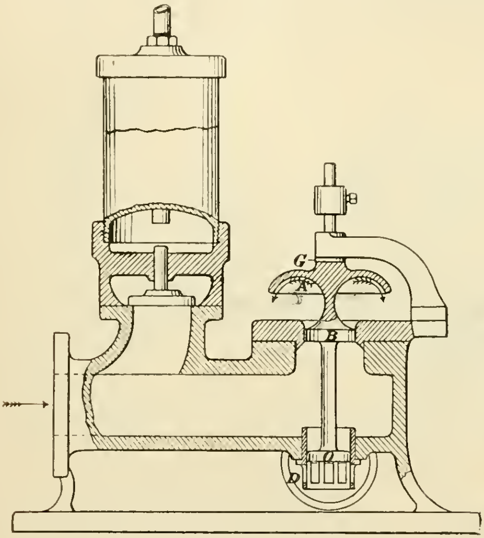


FIG. 11.

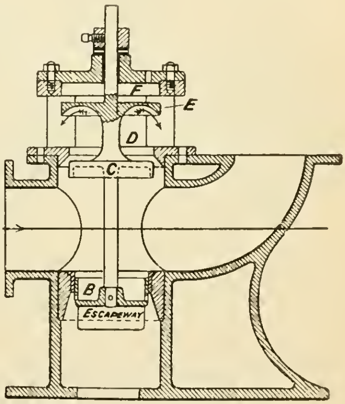


FIG. 12.

Fig. 12 shows a ram of larger size, embodying the features of the two that have preceded, but with the difference that the balancing piston B is less in diameter than the waste valve C, thus permitting considerable closing force from water pressure. The reaction shield E, cushion chamber F and other features will be clear from the drawing and preceding description. In this case a portion of the water was permitted to escape around the balancing piston B.

The ram shown in Fig. 13 was made experimentally and without expectation of permanent use. The sliding fits about the valve would soon either obstruct it or wear it out. The purpose was to apply what may be called the "direct reaction" of the water,

which was discharged through the valve D downward, escaping at J and of course imparting an upward thrust on the valve in proportion to the area of discharge into the pressure. The valve had a long range and closed promptly, cushioning on air in the chamber F and falling by gravity, modified by a weak spring I at the top. This valve developed erratic action. It closed instantly, gave a complete check to the water, but lacked the rhythmic function which has been called "regurgitation," and was consequently unreliable.

Figs. 14 and 15 show an interesting example of practice constructed after the arrival in this country of notices and descriptions of Pearsall's hydraulic engine, but involves no feature of that engine except as to the operation of the escape valve by independent apparatus.

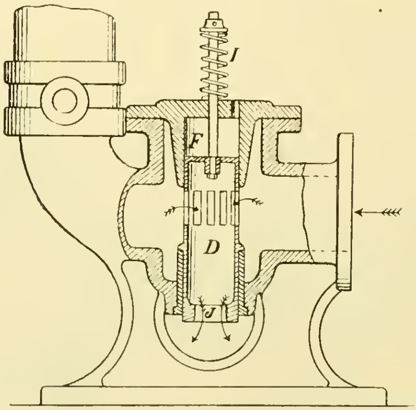


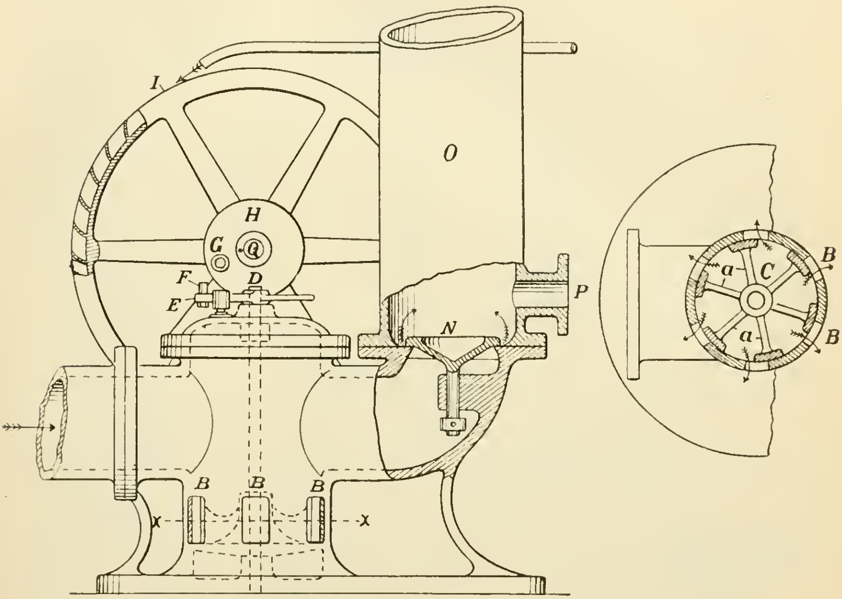
FIG. 13.

The machine, while faulty in several constructive points, some of which will be hereafter explained, is believed to be in some respects an improvement on Pearsall's engine, being capable of the same functions with much less detail. It is less expensive and of a more durable character.

The waste valve C, as seen in Fig. 15, is of the register type and balanced. On the top of its stem D was a cross-arm E having a pin F engaged by a corresponding pin G in the disc H, on the shaft of a small gravity water wheel I, so the valve C was turned one-sixth of a revolution, opening the ports B at each revolution of the water wheel. The periods of discharge could be nicely adjusted by the amount of water supplied to the wheel. The closing movement of the valve was to be performed by a helical spring around the stem D, but it was soon discovered that

this was unnecessary, because the valve closed instantly, owing to some cause not clear at the time, but supposed to be the rush of the escaping water across the vanes *a a*, seen in Fig. 15.

I will not consume time by explaining all the various constructive faults in this machine, but will mention one—the weight and inertia of the water resting on the check valve N, by reason of the vertical air chamber C. This was an impediment that hindered the ram from operating, except at low pressures, and was an oversight scarcely excusable in so obvious a matter. Still, I must claim that common practice, even at the present time, indicates that the extent of this resistance is not recognized by makers.



FIGS. 14 AND 15.

I propose, in future practice, if this branch of work is followed out, to adapt the general features of this machine for pipes 12 inches or more in diameter, when the heads are not excessive.

In respect to the rams represented in Figs. 10 and 11, these have continued to be made to the present time by Messrs. W. T. Garrett & Co., and I was recently informed of a case where one was adopted and approved, after various other types had been tried and abandoned. Some improvements now in course of application will add a great deal to the efficiency of these machines, and adapt them for higher pressures.

This includes, with some important exceptions, my work and

observations respecting hydraulic rams down to the beginning of the past year, when, in reading over some portions of Prof. Henry Robinson's late work on "Hydraulic Power and Hydraulic Machinery," I came across the statement that it had not been found practicable to employ waste valves for hydraulic rams larger than 4 inches in diameter. I was well aware of the fact, as indeed every one is who has experience with the common concussion valves, but I had not before seen recognition of this in a work of authority.

It is true that rams are advertised and sold to receive supply pipes of 6 inches bore, but any one who will examine the matter will find the difference between a 4-inch and a 6-inch ram is confined to a flange at the inlet way to receive supply pipes for one or the other of the sizes, so the limit is about 4 inches diameter, or 12 inches of area, and very few of this size are sold. The true limit is about 3 inches diameter. This circumstance caused me to take up the subject again as time permitted, and, while I am not engaged in manufactures or engineering work at this time, and consequently have not made experiments, I believe that the work done amounts to a substantial advancement of the art. The object of the remainder of my paper will be to present this work, respecting which I invite full discussion.

To proceed in a methodical way, I first laid down the following premises:

First.—A principal loss of energy in hydraulic rams is by the water escaping during the closing of the waste valves.

Second.—The amount of water and energy thus lost is as the time consumed in closing the waste valves.

Third.—The time required for the waste valves to close is approximately as their range, or the distance moved.

Fourth.—The range or distance that common waste valves have to move in closing is as their area.

Fifth.—The destructive effect of the violent closing of the waste valves is as their weight and range, or a product of their weight and velocity.

Sixth.—Hydraulic rams of small sizes, having valves not exceeding 3 inches in area, are reliable and durable. Larger valves are neither, and commonly fail.

Assuming that these postulates represent the conditions to be met, I propose as follows for machines having from 4 to 12 inches bore:

(1) To subdivide the escape valves and increase their number instead of their size, employing from one to a dozen, or as

many as the volume of water requires, thus keeping the range and time of closing down to that required for one small valve.

(2) To employ, in rams of the larger sizes, grid or multiported valves, whereby a larger area is opened by a short movement.

(3) To avoid the addition of any moving parts, and confine the machines to their most simple form, without springs or loose pieces, and to one simple adjustment of the valves.

(4) In machines exceeding 12 inches, to employ rotary lantern valves and an antecompression chamber to avoid concussive action.

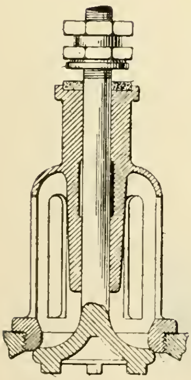


Fig. 16.

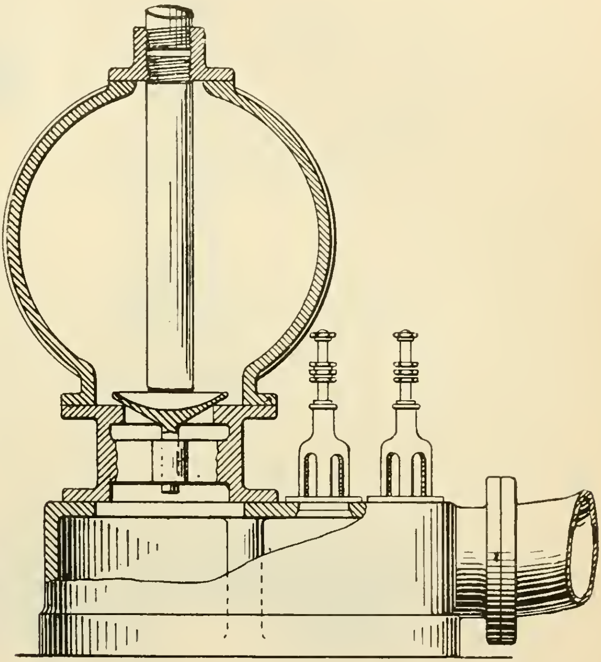


Fig. 17.

On these propositions I set out to design machines that would embody and apply in practice what inference points out, beginning with a unit valve of 5 inches area, shown in Fig. 16. This valve is to form one of the multiple series for rams having supply pipes to 6 inches diameter.

These valves, as will be seen, are supported from the top, clear of sand, arranged to receive weights, adjustable as to range and adapted to systematic manufacture like other water fittings. The seating area is enough to withstand impingement under moderate heads, and will soon be increased by wear under high heads.

The number to be used is from one to six, so set as to operate in unison. They are not essentially different from the valves employed in England, but have larger sliding surfaces for guidance and are more free in discharge.

Figs. 17 and 18 show a plain hydraulic ram arranged to receive valves of the kind shown in Fig. 16, and Fig. 19 is a side view of the air vessel in Fig. 17.

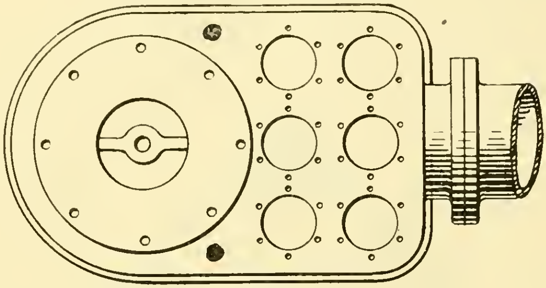


FIG. 18.

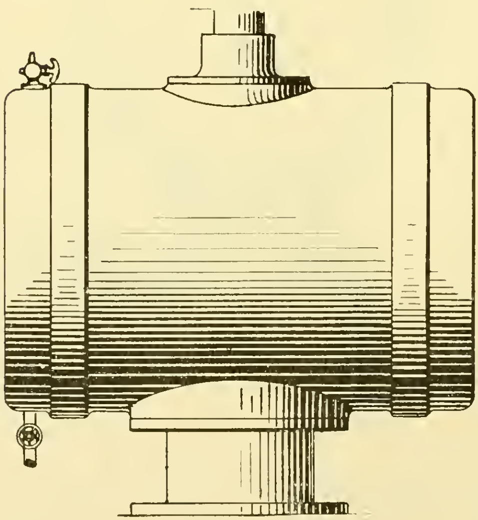


FIG. 19.

There is not much requiring remark in this design, which merely follows, in the simplest manner, the postulates before laid down. The check valves have a very narrow bearing, and the head of water over them is reduced as much as possible by placing the axis of the air vessel horizontally and by mounting the valves on a short nipple, which, below the valves, has a bore much larger than its area. The discharge pipe is set over the check valve, in

order to limit its range, but of course can be led out at any point beyond the valve and below the surface of the water.

By placing a cock in the discharge pipe and shutting off the supply water the air vessel can be drained by means of the cocks shown in Fig. 19.

For rams of larger size; that is, for those having supply pipes from 8 to 12 inches diameter, I propose to employ valves such as are shown in Fig. 20, in which the effective area is 30 inches.

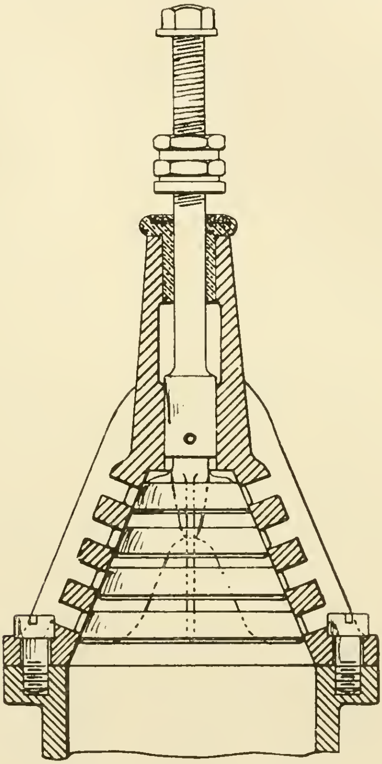


FIG. 20.

These valves are based on a very simple system. The closing angle is made as acute as possible, in order to avoid their "hanging" when closed, and the ports are made multiple, so that the whole area of 30 inches is opened by half an inch of movement, the range and also the shock of closing and loss of water being reduced accordingly without impeding the supply flow.

I do not present designs for machines in which these multi-ported valves are employed, although such designs have been prepared. They involve nothing of interest beyond what the

figures already provided include. The main chambers are made cylindrical in section, and the valves are set on nipples projecting from the top.

I desire to call your attention to the wide use of impulsive apparatus that the physical circumstances of this coast permit. The western watershed of the Coast range of mountains and of the foothills furnishes a diffusion of the water drain into thousands of streams, most of them small, that afford opportunities for raising water by hydraulic rams, if these can be made reliable in action and furnished at a moderate cost in proportion to the duty performed. I may also call your attention to the possibilities of greatly improving these useful implements, judged by parallel experience in other branches of hydraulic engineering.

When I came to California, eighteen years ago, centrifugal pumps were but little employed. The limit of their action was understood to be 40 feet head and 40 per cent. efficiency. Now we have changed all this. The head limit has been more than doubled, the guaranteed efficiency has reached 60 to 75 per cent., thousands of such pumps are in use all over this State, and our practice here has become a standard not only throughout this country, but, to a considerable extent, abroad. Water wheels I need not mention, because all are familiar with the progress made and the results that have followed a practice in impulsive water wheels peculiar to this coast.

In ordinary pumping with piston apparatus there has also been an enormous improvement, if measured by first cost divided by duty. This is illustrated by the fact that the speed of pump pistons, from a velocity of 100 feet per minute, has advanced to double, and in some cases quadruple, this speed.

I have reason to believe that a like advance, but less in degree, is possible in hydraulic rams, and this opinion is based on an examination of most of the machines made during the past fifty years in this and other countries. I mean such machines as have gone into use and have proved of practical value.

In conclusion, I will remark that, in so far as the present paper deals with other than demonstrated facts, it is scarcely the fault of the writer. The subject of impulsive hydraulic apparatus has been singularly neglected in this country, and, when there is a paucity of resources, one has to be content with what is available.

No one can doubt that on theoretical grounds the energy of descending water should, by its impulsive effect, give out more work than if translated through water wheels and pumps, and facts

do not warrant us in assuming that the impediments of application are inherent and insuperable. I propose to go on, as circumstances permit, and will not fail, in future, to present here any results attained of a useful or interesting nature.

DISCUSSION.

President Molera.—We are very much indebted to Mr. Richards for his interesting paper. Hydraulic rams have been greatly improved, especially for raising small quantities of water; but, for raising large quantities of water, they are susceptible of still more improvement. Twenty-five years ago, when I studied mechanics, the great authority on hydraulic rams was General Morin. I do not know that I can repeat exactly his theories as to the hydraulic ram, but, as I remember, the valve of the outflow pipe was opened by gravity. The ram stands nearly perpendicular, the valve is opened a little by the counter-weight, and the flow of water tends to close the valve. As the valve is closing, the area of the opening is diminished, the velocity is increased, and finally the valve is instantly closed, causing a shock, which opens the inlet into the air reservoir. At the moment when the valve closes there is no flow of water, and the counter-weight opens the valve again to its original position. In General Morin's time it was supposed that this shock was a necessary part of the operation of the apparatus, and that is the reason why the inventor called it the hydraulic ram. The effect was similar to the butt of a ram. But experience has shown that this shock is not only unnecessary, but hurtful to the efficiency of the machine. We should like to hear from Mr. Dickie.

Mr. G. W. Dickie.—I have no doubt that the field of usefulness of hydraulic rams will widen as the laws governing their operation become better known. It would be very interesting to know, taking all things into consideration, how a hydraulic ram would compare, in ultimate economy, with a regular pumping machine. I do not think very much progress has been made in pumping machines for the last twenty years. The hydraulic ram seems to be an independent little affair; going and stopping when it feels like it. Mr. Richards, however, seems to have got into the confidence of the machine, and it seems to have become very pliable under his hand.

Mr. Wagoner.—Incidentally, Mr. Richards and I planned, some years ago, a scheme for lifting water in Utah where the circumstances were very favorable to the use of rams. Mr. Richards came to me with the statement that there was no firm in this city that would guarantee to put in a ram with a fall of 25 feet and lift

water, I think, 125 feet (5 to 1) and guarantee a higher efficiency than 50 per cent. We began to look into the matter, and the first thing that attracted my attention was the absurdity of the formula for the efficiency of rams. The formula was based upon that developed by Morin, by which the square of the efficiency is made equal to the constant, minus the ratio of the heads. On the other hand, data are given for rams with ratios of, say 8 or 9 to 1, and almost identical in heads, and where the efficiencies are from 45 to over 90. I think it is highly probable that efficiencies up to 80 and 90 have been attained. But the difficulty appeared to be not in the loss of time or loss of water. I cannot see how these would cut the figure that Mr. Richards imagines. The diagram given by Montgolfier, which I believe is one of the earliest applications of the indicator for making a diagram, the time of closing is about 17 per cent. of the period, and it remains closed about 17 per cent., and is opened in about 10 or 12; making about 46 per cent. from the beginning and closing until fully opened again. I called Mr. Richards's attention, at the time, to the fact that the valve might be easily duplicated in mechanical motion; and, had it not been that the Pearsall invention came out, eliminating the shock, I might have pursued that matter further.

I think, considering the ram as a water engine, we should consider the natural period of the oscillation of the water; and that the period of opening and closing is a function of the pipe.

The experiments to which I refer were made under heads of, say two to ten feet, operating stand lifts, and gave an efficiency all the way up to 90. The efficiency was diminished with the lift, and there is probably another reason for that. At the high drive head the period was 60 per minute, and at the low it was 10 per minute. The weight of the valve was the same. Therefore a large portion of the water would escape in simply giving motion to the valve. In other words, the valve was overweighted.

There is no question that the real secret of improvement of the ordinary type of ram is to be sought for in the proportion of the valve to the work required, but I know of no formula for this.

After taking some data on the largest rams that we could find, we ascertained that they would require six or seven times the weight in iron than would take in a plant in the shape of water wheels and pumps I then dropped the subject.

Mr. Molera. Twenty-six years ago I was sent over to Point Conception Lighthouse, where the first steam whistle was put in, to recommend some plan for supplying the lighthouse with water. The Point is very rocky, and far from any large supply of water, except a small rivulet and a lake about 60 feet below. Under

all the circumstances, the problem seemed difficult, but I concluded that a hydraulic ram would answer the purpose. I put in one there, and during five years that I was connected with the Department we never had any trouble with it, and so far as I know it is there now. In many instances the hydraulic ram is very useful.

Mr. Wagoner.—I would ask Mr. Richards whether he knows anything about Mr. Pearsall's pump, and the present application of it. Some years ago he brought out one to Colorado and was going to pump out a large stream of water—something like 500 inches—to allow the working of placers, but I have heard nothing of it since.

Mr. Richards.—Mr. Pearsall has recently issued circulars, placing his machines before the public. In these he makes great claims for their efficiency. Two were brought to this country. One was 30 inches, and I do not know where that was used; another one, 24 inches, was, as I now remember, taken to some place near Bethlehem, Pennsylvania, and this one, I believe, was successful. I have never heard anything as to the success or failure of the other one.

I think the limitations for large rams, as indicated by Mr. Wagoner, will perhaps prevent their use; that is, the low mean flow in the supply pipe and consequent large dimensions of these. That does not apply in the case of small rams.

I venture again to add to what I have said in the paper in regard to this act of regurgitation in relation to the valves. The weight of the valves usually does not exceed one-half of the weight of the static head under which it operates. I think that in all rams, when working with a proper rhythm of pulsation, the act of regurgitation opens the valve irrespective of its weight. It is forcibly and instantly opened, or, as we may say, closes and opens instantly.

In regard to Mr. Wagoner's remark about the waste of time in the valve closing. It seems to me that the water forced through during the time the valve is closing, is all lost. It is certain that resistence begins as soon as the valve starts to close, and this must be a loss until it closes or until the check valve is opened. I would like Mr. Wagoner to consider that proposition a little further, and see if he is not in error; that is, whether it is not a fact that in taking an indicator card, for instance, one end of the card, representing the pressure before the check valve opens, is not an absolute loss.

Mr. Richards.—The Le Michel machine, which, in this country, has been understood to be an original invention, is not so. It is only a type of the hydraulic ram, of which several modifica-

tions are known in France. The French engineers have paid a great deal of attention to the hydraulic ram. The peculiarity of this machine is, that the ram is placed at the top instead of at the bottom of the fall. There is a valve, as in other rams, and there is an oscillating diaphragm which produces a continuous flow, which is an excellent feature of the machine. The vibration of the valve is exceedingly rapid. The discharge must be carried down below the head, not to exceed 30 feet. The device can be used to draw water from wells, and in this respect it is a very useful machine. Some friends of mine undertook its manufacture here, but there has been nothing done, for the reason that it is very novel in its character, and its method of operating so little understood, that people hesitate to use it.

Mr. Wagoner.—Some years ago I investigated the hydraulic ram for the purpose of raising a large quantity of water in Utah. The fall was 25 feet and the lift 125 feet. I think the cost was seven times greater for rams of the usual type than for water wheels and pumps. I collected data and found the mean velocity of flow in the drive pipe ranged from 0.50 to 2.5 feet per second with an average of 1.2 feet. This flow does not actually occupy more than half of the time of one stroke of the ram. The space passed through being gt^2 and the velocity being $2gt$, it follows that if t be half of the period of a stroke, $v=4\times$mean velocity at the time of closing the clack valve, $=4\times1.2=4.8$ feet.

Before considering possible improvements in rams, it is necessary to consider the various losses, to see if they are remediable and the following analysis of action seems to be correct.

The clack valve closes, and the momentum of the water in the drive pipe is expended (*a*) in compressing air in the chamber (*b*), in shock (*c*) in giving motion to that part of the water at rest, and (*d*) in expanding the pipe and ram. The water comes to rest. Reaction, due to pressure of the air in the chamber, and also to contraction of the iron, reduces the pressure at the clack valve below that due to the head. Gravity, in combination with the factors above mentioned, causes the clack valve to open, and the water comes to rest. Gravity and a much reduced contraction of the pipe sets up a flow which continues until it is stopped by the closing of the valve. It will be seen that losses can occur from pipe friction, from work in giving motion to the clack valve, from shock due to setting the water in motion and to opening the check valve from work lost by water leaking past the check valve, and from expansion and contraction of the pipe. In one case I examined, where the total loss was 47.4 per cent., 5 per cent. was pipe friction and 14 per cent. was work done in moving the clack valve. I

think it possible that a loss may occur through a want of synchronism between the beats of the clack valve and the natural period of oscillation of the water in the drive pipe and ram.

Some experiments seem to show a large loss by leakage at the moment of closing the check valve. Morin's formula for probable efficiency seems to be based upon experiments made under different heads using the same machine. When the ratio $\frac{h}{H}$ is high, only a fraction of the water forced through the check valve remains. This could of course be remedied by increasing the travel of the water. I think there is no doubt that it would increase the efficiency to use a larger drive pipe, with a proper contraction at the ram, and to use another contraction below the check valve as valves, using here a small valve which would prevent back flow to such an extent as usually happens, the snifting valve to deliver under this small check valve.

A ram will not do a maximum of work when working at its highest efficiency. If water for the supply is in excess, the valve can be weighted and the delivery will be in some cases doubled.*

Considered as an engine for moving large quantities of water, the best results will be had by mechanically driven valves, the water cushioning upon air. This leads to the Pearsall type.

Concerning the loss by waste of water after the clack valve begins to close, a diagram made by Montgolfier shows that the water flows 0.564 parts of a cycle. Then the valve begins to close, and is 0.174 in closing, of which time 80 per cent. shows accelerated motion; so that, of the total time (0.738 parts), 0.703 parts are used in giving velocity to the water. These times would correspond to 0.5446 and 0.4942 parts of space; but, as there is no acceleration after the time 0.703, and as there is also reduced area for the flow at the period of closing, it is doubtful whether such loss can exceed 2 or 4 per cent. Indeed, this loss must be common to any valve motion for closing the flow. Therefore, I think the losses occur after the closing of the clack valve. Most probably they are due to a badly proportioned passage way leading to the check valve, and to slip through the check valve.

Mr. Richards.—An economic flow could not well exceed 4 feet per second for water wheels or uptake pipes, and, as the wheels and pumps would cost a great deal more than rams, I think Mr. Wagoner must be mistaken in placing the cost of rams, in the case mentioned by him, at seven times the cost of pumps. Besides, my

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*See *Engineering News*, Feb. 1, 1890. With efficiency = 65 per cent. the yield was only 74.8 gallons per hour, while with efficiency of 52.63 per cent. the yield was 132 gallons per hour.

recollection of the comparison is at variance with the statement, namely: six pipes of 30-inch diameter compared to one of 60-inch diameter. I think that in a fairly computed case there is not much difference between the two if all economic conditions are taken into account.

THE GEOLOGY OF HELENA, MONTANA, AND VICINITY.

By L. S. Griswold, Member of the Montana Society of Engineers.

[Read before the Society, June 26, 1897.*]

GEOGRAPHY AND TOPOGRAPHY.

Helena is about 4000 feet above sea level, the altitude of the country varying from about 3700 feet at the Missouri River across the valley to over 9000 feet in some of the peaks visible to the south and southeast. The range back of Unionville rises to about 6400 feet, which is about 1000 feet higher than Mt. Helena. The valley basin, spreading out below the city, has a length, from northwest to southeast, of about 20 miles, and a width of about 12 miles. To explain what these mountains and valleys mean by presenting a somewhat detailed account of the geology of the city, and showing the geological relation of this small area to the region roundabout, is the object of this paper. The conclusions could be stated very briefly, but I hope and assume that there are some who will be glad to learn something of the method of reaching the conclusions, and trust that those who are familiar with the elements of geology will have patience with my introduction.

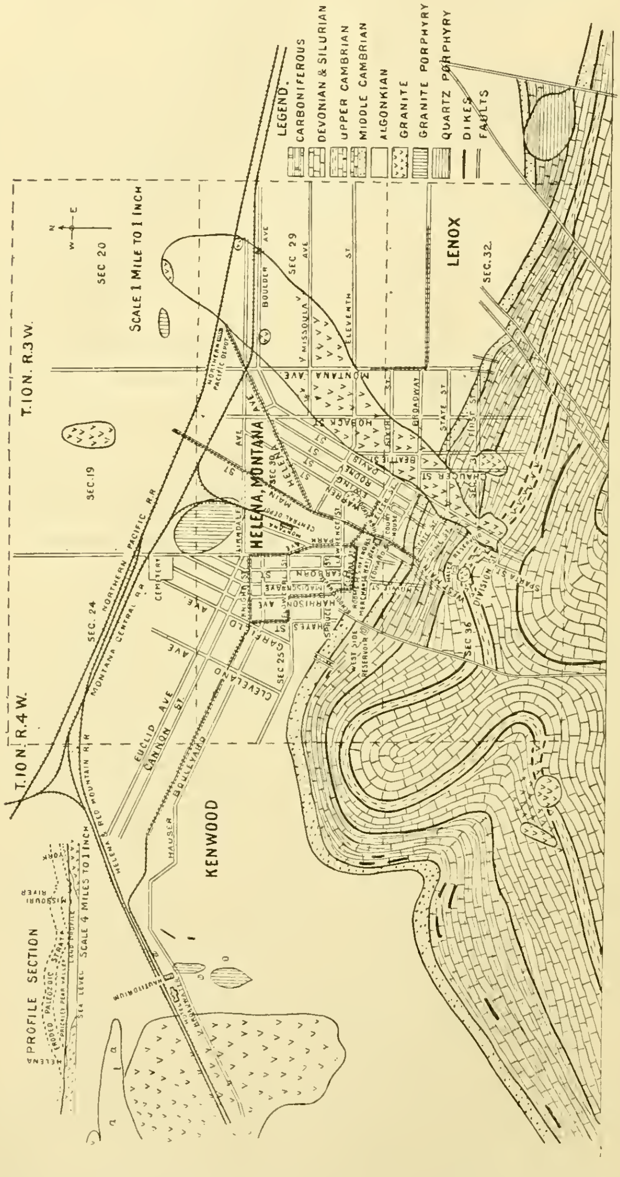
VARIETIES OF ROCKS.

Three groups of rocks are shown—sedimentary igneous, metamorphic, stated in the order of importance in this area. Our theory of origin of this earth as a cooling globe leads us to mention the igneous rocks first, however, for the first crust of the earth was of such rocks, and from them are derived the materials of the sedimentary rocks, chiefly through the mechanical and chemical agencies of air, water, frost, plants and animals. These forces, acting upon any rock masses, disintegrate their surfaces, converting them into soil, sand, gravel, or clay, making heterogeneous deposits called surficial, which cover up the rocks from which they are derived unless the loose disintegrated material is removed by some mechanical agency so that the original rock is left bare. Placer gravels would be classed as surficial deposits.

The materials of disintegration may be carried away as solid particles giving gravel, sand, or mud when deposited in some water body; or they may be carried away in solution and precipitated by direct chemical action, as in some limestones, salt, iron ore, etc., or through the medium of living animals and plants, as in some limestones, coal, etc. But, whatever the method of coming

*Manuscript received January 17, 1898.—Secretary, Ass'n of Eng. Socs.

to rest, the fact of deposition in water usually results in a layered structure, giving strata, and the whole group of rocks is called sedimentary.



Vicinity of Helena.

Molten rock has been breaking through the earth's crust repeatedly since the crust was formed, some reaching the earth's surface and pouring out over it in varieties of extrusive lavas, and

some filling crevices or taking various forms within the crust itself, giving different varieties of intrusive rock. Just about Helena we have only intrusives, though extrusives may be found near Montana City and Blossburg. Certain kinds of intrusive have a place of cooling deep below the surface and occur in large masses; these are called plutonic rocks. Other kinds fill crevices, or occur in sheets cutting older rocks at any angle, or in bodies smaller than those characteristic of the plutonic rocks, and are called dike rocks. The varieties of igneous rocks found about here are given in tabular form, and will be mentioned in detail later.

Rocks either of sedimentary or volcanic origin may become altered by dynamic or chemical action, or both, so that they lose their original texture and become metamorphic rocks. The older rocks of the earth's crust, from their very length of life, are more likely to be metamorphosed than are the younger ones. Thus, about here the limestones have become crystalline and the sandstones have become quartzites. Volcanic rocks, while hot, may induce change in other adjacent rocks. Near here we have shales and limestones which have undergone such change.

VARIETIES OF ROCKS ABOUT HELENA.

Sedimentary.	Mechanical.	Quartzite.
		Shale.
	Chemical.	Limestone.
Igneous.	Plutonic.	Granite.
	Dike.	Granite porphyry.
		Quartz porphyry.
		Diabase.
		Augite porphyrite.
		Hornblende porphyrite.
Metamorphic.	Shale.	
	Limestone.	

GEOLOGICAL HORIZONS.

Rocks having a similarity in composition, texture, etc., or containing similar fossil forms, are grouped into horizons, each horizon representing a geological age with a definite name. Each age represents a vast duration of time; and its prevailing conditions are manifested by the character of the rocks and by the kinds of living things found in the form of fossils. Thus certain forms of shell, of fish, or of plant may serve to correlate rocks widely separated, assigning them to the same geological horizon. In this way the sedimentary rocks about Helena have been grouped into geological ages.

TABLE OF GEOLOGICAL FORMATIONS.

Recent.	Surficial deposits.
Tertiary.	
Cretaceous.	
Juratrias.	
Carboniferous.	Quadrant quartzite. Madison limestone.
Devonian.	Threeforks limestone.
Silurian.	Jefferson limestone.
Cambrian.	Upper or Gallatin. Middle or Flathead.
Algonkian.	
Archæan.	

The table shows in the left-hand column a list of the greater geological horizons, and to the right are certain special names which have been used by the United States Geological Survey to distinguish characteristic horizons in the country farther south. With the exception of the Archæan, there are found around Helena rocks belonging to all the great divisions, although the Tertiary is as far away as Blossburg, and the Cretaceous and Juratrias near Elliston; the others are found in the immediate vicinity of the city. The geological section from Algonkian to the top of the Carboniferous appears to be conformable; that is, the beds were laid successively one on another so that the bedding planes are parallel and no disturbance or interruption between the ages caused one set of strata to be deposited at an angle with those below. The surficial deposits are unconformable.

We learn that in other parts of the State the deposition of strata continued conformably to the top of the Cretaceous and we may presume that the conditions here were the same. Then followed a time of active mountain building which may be going on even now.

ELEMENTS OF STRUCTURE.

In mountain building the earth's crust is uplifted, in this case above the sea floor, bent and broken and exposed to wearing away by all the subaërial forces. Arches in the strata of the crust are termed anticlines, hollows synclines; when rocks are broken along a plane and movement takes place so that the faces no longer match one another they are said to be faulted. Into sedimentary strata or other volcanic rocks molten rock may push or melt its way, forcing apart the older rocks or dissolving them in the molten mass. Consequently the continuity of any rock mass may be interrupted by a newer volcanic rock.

EROSION AND ITS EFFECTS.

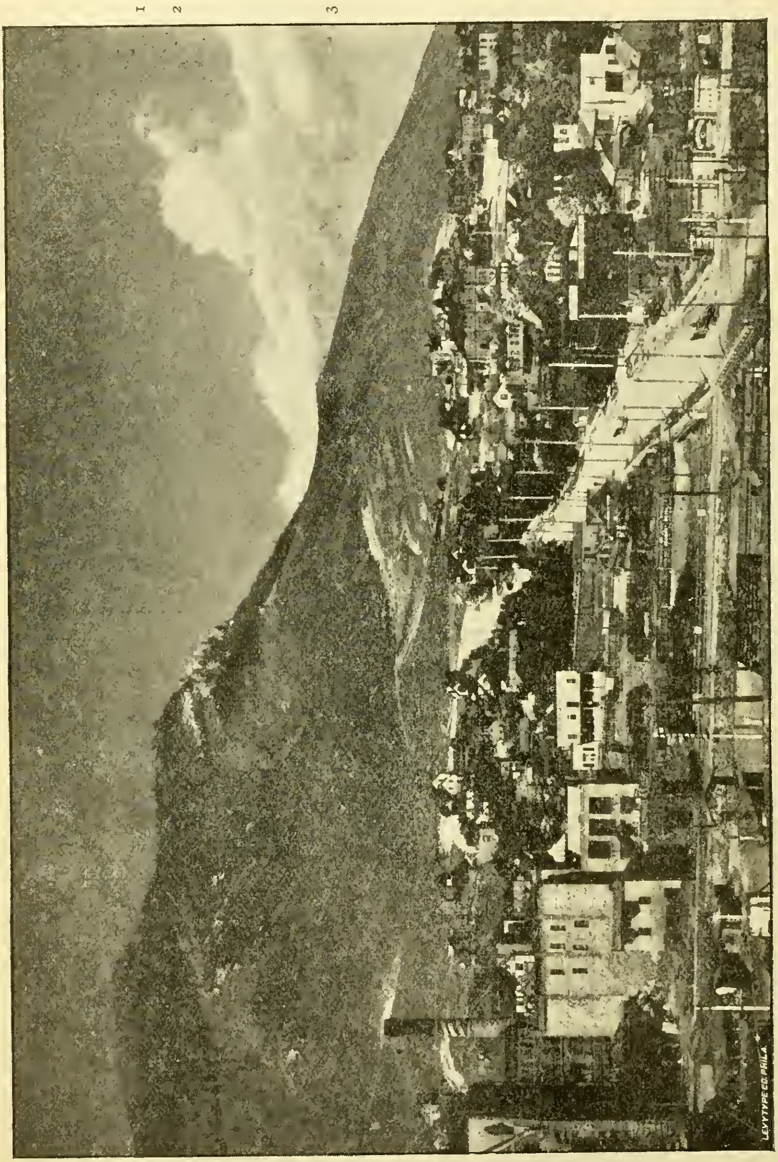
As soon as a land mass arises above the sea various agencies, acting under the law of gravitation, tend to reduce it below sea level again. Running water is perhaps the most important of the forces of denudation and acts more vigorously the steeper the slope. So mountain masses are strongly attacked by the water falling upon them; the water finds hollows to gather in, cuts these hollows into channels, deepens these in turn to ravines and gulches, and the gulches widen and flatten into valleys. Anticlines in particular are exposed to erosion and after a time we may find only the rim of a great dome left to tell the story of its former greatness.

It is with the eroded mountain structures that the geologist has to deal, reconstructing mountain masses from the ruined walls visible in all exposed ledges, each outcrop telling its story of a pillar, or a buttress, or course in some past mountain structure. Some rocks, more resisting than their neighbors, stand above the general level of the landscape and can be followed easily; others are easily disintegrated and seldom show through the covering of their own waste. The former class may be called ridge-makers, and serve the geologist well in outlining his structures, and in giving suggestions to be verified by studies of the other rocks. Such a ridge-maker has been used very effectively in working out the geology of this vicinity.

SEDIMENTARY SERIES ABOUT HELENA.

The west-side reservoir is situated in a depression between two hills which, taken together in their extent, stretch about northwest and southeast. To the southeast the ridge extends with uneven declining crest to the south end of South Benton avenue, and the formation crosses the gulch just north of City Hall. It rises again in the bell-tower ridge which underlies the Catholic buildings. About Davis street an intrusion of granite interrupts the ridge, but east of Davis street it stands up again strongly and can be followed easily by the eye in its general course south of east even to the neighborhood of Montana City. To the northwest of the west-side reservoir this formation sweeps northwest, west, and south around Mt. Helena, sometimes apparent as a ridge but more often appearing as a steeper and rougher part of the mountain slope, an escarpment situated about a third of the way up the slope. This resisting formation is a metamorphosed sandstone or quartzite having an average thickness of about 300 feet. From its character and position in the geological section it is regarded

as identical with the Middle Cambrian or Flathead quartzite, well known in the southern part of the State. This is an important formation, because it marks the dividing line between the Paleo-



Mt. Helena from the East.

1. Silurian limestone.
2. Upper Cambrian limestone.
3. Middle Cambrian quartzite.

zoic and Azoic rocks, no lower Cambrian strata being as yet known in this region. All the sedimentary rocks on the north side of the Cambrian quartzite are classed as Algonkian. On the south side are found the younger Paleozoic formations.

Another very useful formation in determining structure occurs at the top of the Gallatin division of the Cambrian. This is a dark gray to black shale which is just the opposite of the ridge-making quartzite in being a favorite formation for valley lines. It is useful because it contains an abundance of little shell imprints by which it can be identified; and while it seldom affords ledges for examination as the quartzite does, yet the little fragments of shale found on the surface tell their story just as effectively as bold cliffs. The shale and quartzite together are very useful in outlining the geological structure because each is strongly characteristic and each easily found, the shale occurring between two massive limestones as a hollow or low slope, and the quartzite as the outer line of foothills.

Between these two are found first overlying the quartzite beds of micaceous shale soon succeeded by calcareous shale becoming more strongly limestones as we rise in the section. A massive bluish gray limestone comes next and continues to the Gallatin shale. This massive limestone is the one forming the cliff just below the east-side reservoir and the great bluffs of Mt. Helena, and is placed in the Gallatin division of the Cambrian. The calcareous shales are placed in the Flathead division and have a topographic expression in a low slope between the quartzite and massive limestone escarpments or in an actual depression back of the quartzite. The calcareous slates have a thickness of perhaps 450 feet, the massive limestone of 400 feet, and the Gallatin shale 150 feet, giving with the quartzite a total thickness for the Cambrian of 1300 feet.

On top of the Gallatin shale come the Silurian strata, for the most part massive limestones, gray or bluish, but containing dark blue limestones and black, red and gray shales. The limestones of this horizon form the crest of Mt. Helena.*

Fossils have not yet been found in this series, so it cannot be subdivided or separated from the Devonian horizon, which has been identified in Southern Montana. The Carboniferous limestones which form the peak of Mt. Ascension abound in fragments of crinoid stems, so here can be drawn another line of division.

*Through the kindness of Mr. D. P. Patenaude in presenting the photograph we may note the topography of the different formations composing Mt. Helena. Silurian strata form the peak and backbone of the mountain. The Gallatin shale is well marked by a line of depression, below which the massive Gallatin limestone gives cliffs and steep slopes. The Flathead quartzite finds expression in a steeper portion of the lower slope of the mountain, though on the left side of the view it forms an outlying ridge.

The Carboniferous strata, however, do not come within the city limits, and it is only possible that the Devonian rocks should be represented on the map in the vicinity of Dry Gulch. The Silurian and Devonian have a total thickness of perhaps 900 feet.

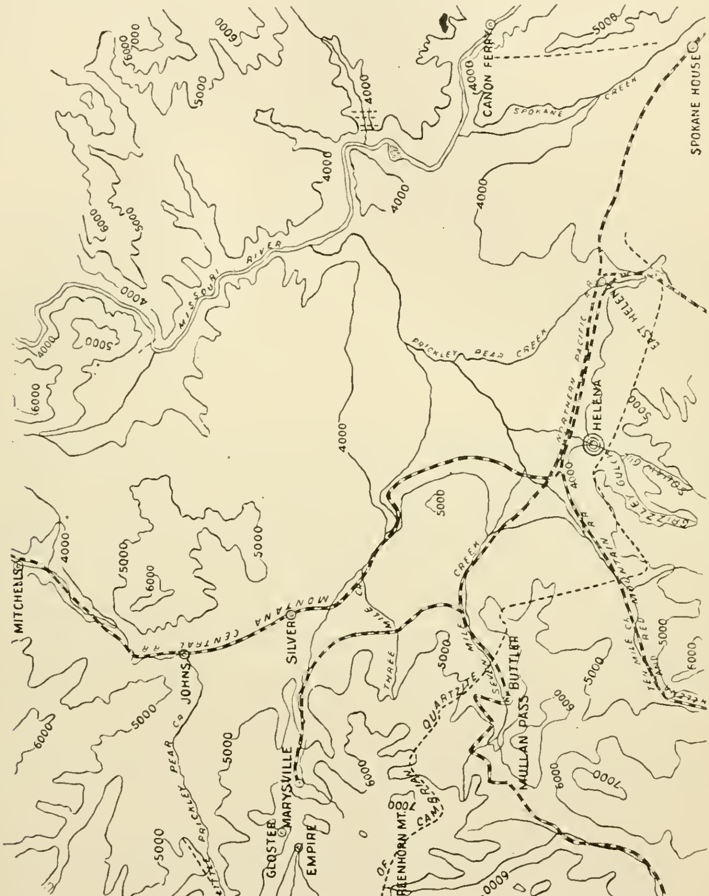
The massive beds of crinoidal limestone coming at the base of the Carboniferous contain small corals, and a few shells have been found. The whole limestone is crystalline so that the organic forms are often obscure. The dark bluish gray crinoidal limestone is succeeded by a homogeneous light gray limestone becoming white and coarsely crystalline at the top, the whole being known as Madison limestone, a characteristic mountain-maker in the southern part of the State, weathering into picturesque crags. It has a thickness of 1600 feet or more.

A decided change in the character of deposition ended the limestone formation and ushered in another sandstone which like the one in the Cambrian has been altered to a quartzite. In this vicinity only patches of this quartzite are found between the limestone and the great mass of igneous rock which cuts off the sedimentaries on the south. The greatest thickness noted is about 500 feet. As this quartzite is regarded as Carboniferous in age, it makes the thickness of the Carboniferous series 2100 feet or more. The total thickness of the Paleozoic rocks is seen to be over 4300 feet.

The Algonkian rocks consist of slates of irregular texture, varying from clay slate to micaceous, sandy, or calcareous varieties which become even quartzites or limestones. The bedding planes are very commonly uneven and the rocks seem to be filled with knots. Some of the limestone is oölitic. Closely underlying the Cambrian quartzite the slate is often strongly red in color, well shown on South Benton avenue. Near Lenox the red slate is very thin and greenish gray prevails. Northwest toward Marysville and east across the valley the red slates have great thickness. The lowest of the Algonkian rocks yet seen are greenish gray slates, often calcareous and knotted, occurring in massive beds. These are the slates of the Marysville and York mining districts. The Algonkian slates seem to conform to the overlying strata in the dip of their beds, but there are many small folds developed in this series, and as no subdivisions have been established and followed out it is difficult to determine the thickness of the series; 5000 feet does not seem too large a total.

VOLCANIC ROCKS ABOUT HELENA.

Granite.—I have already mentioned the fact that our sedimentary rocks are bounded on the south by a great mass of igneous rock. We also have igneous rocks in abundance within the city. A granitic mass underlies a considerable area on the east side, beginning in Dry Gulch south of First street. The gulch is



VICINITY OF HELENA.
Scale 5 miles to 1 inch.

cut in the granite though the rock does not rise high on either slope. The granite follows the course of the stream to the northeast, widening from about 100 yards at First street to nearly half a mile in the vicinity of Missoula avenue. It becomes difficult to determine what is the bed rock as we get farther down the mountain foot where the surficial deposits are so deep, but it would

seem probable that the small outcrops seen near the railroad tracks indicated an extension of the granite area to embrace them.

A small granite dome appears in the southeast part of the school grounds on Warren street, extending between Eighth and Ninth avenues. Another area, 200 yards or more in diameter, appears at the head of Chaucer street, extending across Beattie street and reaching north and south between First and Kentucky streets. These two areas, doubtless, are closely connected below the present surface with the larger area shown along Dry Gulch, and the covering of sedimentary rocks between these areas is probably a thin one. About half a mile south of Lenox granite dikes are shown in several prospects, indicating another place where the underlying granite approaches the surface.

Near Rodney and Division streets, near Sparta street and just south of the reservoir, granite appears in a somewhat altered condition, representing contact phases; especially is the granite origin of the rock obscure at the reservoir where the rock intrudes through the Gallatin shale and takes a very dark color and fine grain.

A small granite mass prettily defined is found in Grizzly Gulch, half a mile above the junction with Oro Fino. The area is nearly circular, cut in two by the stream, and a little quarrying has shown a pretty building stone. This dome also appears in the Gallatin shale, and contact phases of the granite are found in the shale belt to the east, and in the limestone on the north. A larger granite area is found surrounding the warm springs above the Broadwater Hotel, somewhat irregular in outline with diameters of about a mile. Driving along the Ten Mile Valley, one cannot help noting this basin surrounded by hills of slate, whose smooth outlines are occasionally broken by jagged outcrops, contrasting strongly with the abundance of granite ledges characteristically rounded in outline and surmounted by rounded boulders. In the southern part of the area several granite monuments left by the erosion of the surrounding granite are worth a little walk to see.

On the north side of the ridge which confines this basin on the north, granite appears again, doubtless belonging to the mass on Ten Mile Creek.

On the east side of Last Chance Gulch and half a mile north of the railroad tracks on the electric line to the University a low hill extends north and south, abounding in granite boulders showing for the most part contact phases of the rock. It seems probable that granite reaches the surface again at this locality.

The abundance of granite areas around the city would lead us to believe that granite underlies the whole district at no very profound depth.

Granite Porphyry.—A rock closely associated with granite, and indeed regarded as coming from the same deep-seated mass of molten rock or magma, but having in general the characteristics of dike form, is found comprising Capitol Hill and in a smaller area with east and west extent about a quarter of a mile north of the Northern Pacific station; also a short distance east of the Natatorium between the railroad tracks and the Boulevard, and south of the Natatorium comprising much of the hill. This rock has the same chemical composition as granite, but a porphyritic structure, caused probably by the difference in conditions of cooling, so it is called granite porphyry.

Quartz Porphyry.—Still another phase of the granite magma is found about a mile southeast of Lenox, a variety in which the minerals are fresher than in the others so believed to be younger, a variety which commonly occurs as an extrusive rock or lava, but in this case pretty surely intrusive. It is called quartz porphyry.

Basic Dikes.—Volcanic rocks containing less silica and with feldspars of lime-soda composition, instead of potash, are called basic in contrast to the acidic group of which granite is a leading example. We have several dike rocks, of the more basic sort. It is not very easy to determine these rocks, because their crystallization is fine and their mineral components cannot be distinguished without the aid of thin sections of the rock examined under the microscope, a work for which there are no facilities here.

The dike rocks have a strong tendency toward interbedding though sufficient evidence of cutting across the planes of stratification is found to decide their nature. Most widespread is a dark green rock, commonly with many small holes of rusty appearance, which shows an outcropping thickness of from 5 to 30 feet, sometimes divided into two parts. The holes result from the decomposition of augite or olivine and the rock seems to be a diabase. It is seen best developed along the south side of the Reeder's Alley Gulch, in the micaceous beds just above the Flathead quartzites. A small thickness of the same rock was noted on the west side of Mt. Helena. The same rock was found again in about the same geological position, a quarter of a mile south of Lenox. This diabase is also seen cutting across the Flathead quartzite on South Benton avenue, and in the slates of Lynndale avenue, at the southeast end of the granite porphyry of Capitol Hill.

Another dike rock follows a belt of black shales in the Silurian closely, and has been noted from half a mile east of Dry Gulch, following the rock structure west of the gulch and changing in direction with it from northwest to west, southwest and south on the east side of Oro Fino Gulch, extending beyond the city limits. The rock is tough and dense in texture, dark green in color, but mottled with many white spots on weathered surfaces. The white spots look like plagioclase (lime soda) feldspars. What look like augite crystals are also seen, and the rock perhaps belongs to the gabbro group; it may be called an augite porphyrite provisionally. This dike is sometimes 40 feet wide.

The third variety of dike is found interbedded with Algonkian limestones east of the Natatorium quarter of a mile, and crossing the ditch on the south side of the Boulevard. It extends for 200 or 300 yards continuously on the hill slope, having a thickness of about 6 feet, then disappears for a distance, to come to the surface again on the east side of the gulch which debouches at the Natatorium. This is another dark green rock of fine grain, but distinguished by the numerous clusters of hornblende crystals which have the habit of radiating from a center. I call this rock provisionally a hornblende porphyrite.

An undetermined dike rock of dark color and fine grain was found northwest of the Natatorium on top of the ridge.

An igneous rock of less basic character follows the micaceous beds above the Flathead quartzites. It is found first on the northeast side of Mt. Helena close to the quartzite, and continues for several miles to the west in the same position. On the west side of Mt. Helena another bed of the same rock appears 30 or 40 feet higher in the series, and apparently holds that position to the west. These rocks are too much decomposed for satisfactory determination, a porphyritic structure is clear, however, and diorite porphyrite is strongly suggested as a specific name.

INFLUENCE OF VOLCANIC ROCKS ON SEDIMENTARIES.

Molten rock intruded among sedimentaries or older volcanics causes changes to take place in the sedimentaries by heating them, or by sending among them hot vapors and liquids bearing minerals in solution. The alterations in the older rocks are commonly confined to a limited distance from the boundary of the molten rock giving what is called contact metamorphism; the influences may be felt, however, for a long distance by means of cracks or crevices in the older rocks, and minerals may be segregated along such lines giving rise to fissure veins. Contact metamorphism

may consist of a rearrangement of the mineral components of the original rock alone or with the addition of mineral matter from the new rock. Different kinds of rock vary much in their susceptibility to metamorphism; sandstones or quartzites are little altered, shales are commonly changed very noticeably in character, the most common change being from a weak friable texture to a hard flinty one. Such a change has taken place in the Gallatin shale in contact with the granite up Grizzly Gulch, near the east side reservoir, and east of Dry Gulch, where the shale belt is metamorphosed for half a mile, the Hawkeye Mine being in this belt. The way in which the granite has selected this shale belt as a suitable line of intrusion is very striking, the adjacent limestones being unaffected except up Grizzly Gulch. It would seem as though the granite made its way upward by melting the dark shale and taking the shaly material into itself, for we find stages of the granite which are almost black, then rock which cannot be called either igneous or sedimentary, then black flinty rock with white spots which one would term a metamorphic shale, and finally recognizable shale indurated yet still preserving the fossil forms. The Gabbro dike in the Silurian strata has also been intruded along a line of shale. The Algonkian slates on the north side of the granite basin of Ten Mile Creek (in the area lettered *a*, *a* on the map) have been altered to hornstone and porphyry of many colors and textures, in some specimens the planes of sedimentation can be seen; other samples would be regarded as volcanic rocks. Curiously no ledges of these rocks appear, though the surface is strewn with boulders.

Limestone has been strongly metamorphosed in only one locality, half a mile up Grizzly Gulch, on the north side of the granite dome. Vesuvianite has been developed here, a mineral which is a silicate of lime and aluminum with iron, magnesium and sodium, thus appearing to be a rearrangement of the mineral constituents of the limestone. The peculiar mottled appearance which this mineral, with its pale yellow, green, or red crystals gives to the limestone, has attracted the prospector to this locality, and numerous holes attest his diligent search for more valuable minerals. In these pits it is seen that the granite is but a short distance below the surface, and that the alteration in the limestone extends only a few feet from the plane of contact.

STRUCTURE.

The earth's crust in this vicinity has been profoundly disturbed by the forces of mountain building. The mass of sedimen-

tary rocks that had been quietly accumulating from early in Algonkian time to the end of the Cretaceous, aggregating in thickness perhaps three miles, then became influenced by the stress ever existing in the earth's crust and wrinkled in broad folds. The erosion of the crests of the folds as they were exposed to denudation weakened the crust locally and decreased its load so that a continuance of mountain building was favored. In the basins of this time some sediments were accumulated Tertiary in age. A remnant of these basins is found at Blossburg, where there is an area about a mile in diameter consisting of slightly consolidated strata of gravel, sand and clay with thin beds of coal. The erosion since Cretaceous time has been immense, and our present mountain ranges are only the ruined fragments of former great mountain structures. Starting with our local geological structure let us reconstruct the greater mountains of former times.

Our city map shows us a great series of rocks in general tilting southward, a southward dipping monocline as the geologist terms it. This condition of the strata implies either that they have been upturned along a great line of fracture, or that to the north of us a great arch of strata has been worn away and that somewhere to the north the other side of the arch will come down to give us another monocline. A wider examination of the country favors the second idea. If the ground were level and our monocline were simple in structure, the belts of rock composing it would be represented by straight bands across the map; but the combination of mountain and gulch with strata inclined at a general angle of about 30° causes the bands to pass in slightly waving lines across the map; and add to this the fact that our monocline is both bent and broken and we have a general explanation of the irregular distribution of the symbols representing the sedimentary rocks.

The great feature that we notice is the double loop of strata about Mt. Helena, the strata bending to the north around the peak, and to the south along a line of depression on the west side of the peak. The north bend outlines a depression or syncline in the structure, the south bend an arch or anticline. Simple depressions or domes would be completely surrounded by a given formation, but the major axes of this syncline and anticline are tilted so that the various formations do not close around them. We should note that the syncline makes the mountain peak and the anticline a line of depression. This is in accord with the belief of geologists that the syncline is a district of compression and consequently of greater resistance to erosion, while the anticlined arch

is a place of stretching and breaking, so more easily worn away, becoming valleys in our topography. The anticlinal arch is of much less size than the syncline, so its valley is comparatively unimportant.

From the district of disturbance at Mt. Helena the monocline extends to southwest and southeast in pretty constant direction. On the east, however, there are numerous breaks across the formations which disjoint the strata to a greater or less extent. Since the resisting formations are more or less crushed along these fault lines, the lines may afford easy erosion and become gulches or valleys. The west side reservoir occupies a depression of this sort, the formations on either side do not match at all and we find that the quartzite horizon has been so completely dislocated that the top of the formation on one side of the break does not even touch the bottom of the formation on the other side. Platting the rocks on the map as we find them on the ground, we see that measuring the distance between corresponding parts of the formation they have a horizontal offset of 500 feet. To get this offset in beds dipping somewhat less than 30°, with an allowance for the hill slope, requires a vertical movement of about 290 feet. As fault lines usually approximate the vertical, a vertical measure is taken to estimate the throw of a fault. A break of such amount as 290 feet should be traceable for some distance, and it is distinguished with comparative ease to the south where it crosses the Gallatin shales, but in the massive limestones it is not so easily followed; the line passes across the junction of Grizzly and Oro Fino Gulches and up Oro Fino Gulch. To the north of the reservoir the Algonkian strata afford too few outcrops to admit of tracing this fault; possibly the small lines of slipping seen in the cut on Lynndale avenue, near the Montana Central Railroad, belong to this larger line of dislocation.

A quarter of a mile northwest of the reservoir two small breaks near together are noted in the quartzite giving offsets of about 60 and 40 feet. Offsets of such size are not strongly noticeable even in the quartzite and they have not been traced at all in the other formations. They represent vertical movements of about 20 and 30 feet. Note that these two small faults have the upthrown side on the west, whereas the larger fault at the reservoir has the upthrow on the east side.

Other faults are found in the east part of our area. Where a south extension of Montana avenue crosses the quartzite is a dislocation with throw of about 30 feet, and 100 yards to the east is one of about 15 feet. Two stronger faults about 100 yards apart

cut the quartzite within a quarter of a mile, and these dislocations apparently continue about parallel across the Gallatin shales. The vertical movements are about 110 and 230 feet, the upthrows being on the west side in each case. These two fault lines strike about northeast and southwest, the ones previously mentioned being more nearly north and south.

A little more than half a mile farther south of east we cross another fault line much stronger than any previous one, extending northeast and southwest also. The offset on the surface is about 850 feet, and the strata are dipping over 40°, so the vertical movement necessary is about 765 feet. Still another fault is encountered half a mile southeast from the last. The dislocation in this case is seen to be about the same as for the last fault, the Upper Cambrian limestone overlapping the Lower Cambrian quartzite. The last fault strikes but little east of north, so it would meet the northeast to southwest fault in less than a mile to the northward. The throws of the faults are opposite, so it becomes evident that between these faults a wedge-shaped block has sunk for about 765 feet. The relative depression of the block of strata is not now visible in the topography for erosion since the time of faulting has given the country the same general elevation. A strong gulch marks the line of the northeast-southwest fault toward Unionville. The eastern fault seems to break into smaller faults, and is strongly marked in the landscape. Some cross-cuts on this latter fault give us a notion of its internal construction. The greatest part of the movement is confined between two walls nearly vertical, which vary from 5 to over 40 feet apart. The walls are ground smooth and show scratches or striæ made by the movement of one rock mass on another, slickensided as it is called technically. Between the walls is a heterogeneous mass of material ground from the walls and identifiable with them, as for example, quartz porphyry, or made over by the introduction of other mineral matter, a process favored by the fissuring, vein quartz being a common product. Much material in this large fault is ground to clay comparable to the talc of an ordinary vein. In fact, fault lines are fissure veins, but, as we know, fissure veins are only mineralized occasionally. We may follow the general structure further by referring to the small scale map copied from the United States Geological Survey where a dotted line traces the course of the Flathead quartzite and outlines the structure of the sedimentary rocks. This formation strikes south of west from Mt. Helena nearly to Nelson Gulch, then turns almost north for about six miles when its general course changes to northwest, though the structure is complicated

by some sharp curves. East of Greenhorn Mountain it bends to the south around the peak, but recovers its northwest course passing near the Bald Butte stamp mill. A few miles beyond the mill it trends north crossing Lost Horse Gulch about three miles below Empire. The northward course is continued across Little Prickly Pear Creek when it bends towards the northeast, probably crossing Little Prickly Pear Cañon near Mitchels. At the Gate of the Mountains the Cambrian comes down at a steep angle and the Cañon of the Missouri is cut through the Paleozoic limestones. On Trout Creek, below York, the quartzite is well exposed in two small synclines. On the Cañon Ferry road, west of the river, the quartzites and accompanying formations are crossed, showing a dip to the east. The formation trends east of south in the Spokane Hills and may be seen in the hillsides east from Clasoil station. A mile or more southeast of East Helena the quartzite strikes northward, but must turn eastward toward Spokane Gap in the low sand hills east of East Helena. It crosses Prickly Pear Creek about two miles south of East Helena, and then turns north of west to our starting point. This incomplete sketch of the Flathead quartzite supports the idea that the Prickly Pear Valley was formerly arched over by the Paleozoic and other strata belonging to the geological section. The weak geological dome has been reduced by the wear of time to a topographical depression. A profile section from near Helena to the vicinity of York may illustrate the structure more clearly. You will note how insignificant in the black profile line appear the mountain slopes which seem to us so steep, though as it happened the line selected did not cross the steepest slopes. At the Helena end of the section the stratified rocks are seen to be cut off by granite at no very great distance below the surface. At the York end some are cut off, but the greater thickness arches upward again to come down elsewhere. Of course all that is indicated above the profile line, and indeed what is indicated below is inferred from observations made along the profile line itself, yet there is satisfaction in feeling confident that whatever error there is in these hypothetical projections is on the side of simplicity. As a matter of fact the ancient Prickly Pear dome was doubtless much more complicated than is represented, but observation and inference justifies only as much as I have represented.

A brief summary of the geological history of the region is: Uninterrupted period of accumulation of strata from Algonkian to the end of Cretaceous time. Then elevation of the region above sea level and great erosion which pretty well defined our present

mountain ranges. In the valleys formed by this erosion Tertiary sediments were deposited, and these deposits as well as a little more of the consolidated strata of the mountains have since been washed away. No traces of glaciation have been observed in this neighborhood, and only around the higher peaks, like Mt. Powell, west of Deer Lodge, was important work done by ice in the Glacial epoch.

ECONOMIC GEOLOGY.

Very probably some are asking of what practical value is all this, meaning what bearing has it upon the great matter of dollars and cents. In this district geology becomes of importance in relation to mining, in other districts the science is of value in connection with soils, water supply, oil, natural gas, etc. Within the limits of our large scale map we have no large mines, but we have illustrations of different varieties. The greater fissures or fault lines have attracted mining at several points. On the large fault at the eastern side of the map some gold quartz has been found. On the other side of the wedge about half a mile south of Lenox the vicinity of the Herbert placer, Try Lode and Small Hopes, I understand that good ore has been mined and shipped. Some good ore has been taken from a small mine, the Vernon, on the 230 foot fault at a place about half a mile south of Broadway on a projected extension of Montana avenue. Prospect holes and drifts have tested other fault lines.

The Hawkeye Mine, near the south end of Chaucer street, seems to be the pre-eminent example of a mine produced by contact of volcanic rock with sedimentaries. Ore has been reported also in Mr. Purcell's limestone quarry on Chaucer street, and such ore would represent a contact product with the adjacent granite.

In the '96 Mine and the Cosmopolitan we seem to have the possibilities of ores segregated from the adjacent strata, for the ores occur in horizontal pipes which lie nearly along the plane of stratification of the mountain mass; however, some fissuring is apparent in these mines and the distance to volcanic rocks is not great, so it is not possible to say just what influences operated to deposit the ores in these mines.

These examples from this little district are sufficient to suggest, I think, that geology is of value in understanding mineral deposits which depend upon stratification, upon contacts with volcanic rocks, and upon fault lines, so that such labor as the geological map of Helena represents, of the same kind as is done by the United States Geological Survey and the Geological Surveys of many States, is justified from the practical point of view.

RECENT DESIGNS IN STEAMSHIP CONSTRUCTION UPON THE GREAT LAKES.

By Richard L. Newman, Member of the Civil Engineers' Club of Cleveland.

[Read before the Club, December 28, 1897.*]

Some two years ago, when approaching the city of Cleveland by the Lake Shore Railway, and seeing before me, for the first time, the broad expanse of Lake Erie, I began to realize the magnificent extent of these great inland seas; and, as I was soon brought into direct contact with many of the splendid steamships traversing these waters, I began to appreciate the stupendous proportions of the lake traffic. My admiration for the small body of men who have made this traffic possible was simply unbounded, and I would therefore ask you to regard my remarks this evening, as made, not in the spirit of criticism, but rather as suggestions from a fellow-worker whose only desire is to see the art of shipbuilding, on these great lakes, progress as it ought and hold its own in such a manner that the ships built here may compare favorably with those built on the coast. No one realizes better than myself the difficulties with which the naval architect has here to contend, the most important being a natural one,—namely, the limited draught of water,—and another, a structural one and necessitated by the demand for the prompt handling of cargo,—namely, the number and size of cargo hatches.

A study of the stresses to which a ship may be subjected is most appropriate just now, as we shall, in a very few months, witness the advent of several fresh-water leviathans of a length such that if one had even suggested it but a few years ago the proposer would have been considered a fit subject for a lunatic asylum. The demands are at present for boats of the largest practical dimensions, limited only by the tortuous channels of the connecting straits and the facilities obtainable at the ports of entry. We are nearing the day when we shall see steamships nearly 500 feet long, bringing down, every trip, over 7000 gross tons of ore, and towing a consort having a similar carrying capacity, but of not quite the same lineal dimensions. The naval architect has therefore to rise to the occasion and satisfy these demands in such a manner that the undertaking will bring credit to himself and to the owner. While providing ample strength, he must also have in view the necessity of not overburdening the

* Manuscript received January 18, 1898.—Secretary, Ass'n of Eng. Socs.

boat with material. I remember well a remark made to me by a very celebrated engineer, Mr. A. E. Seaton, the author of the well-known text-book on "Marine Engineering," some ten years ago, when I had the nominal charge of his drawing office. He remarked to me (over some work I was doing), "Any man can build an engine if he is allowed to put in as much material as he likes; but the engineer of to-day is the trained man who can build the best engine on the least quantity of material." I know of no expression more appropriate than this to be applied to the ships

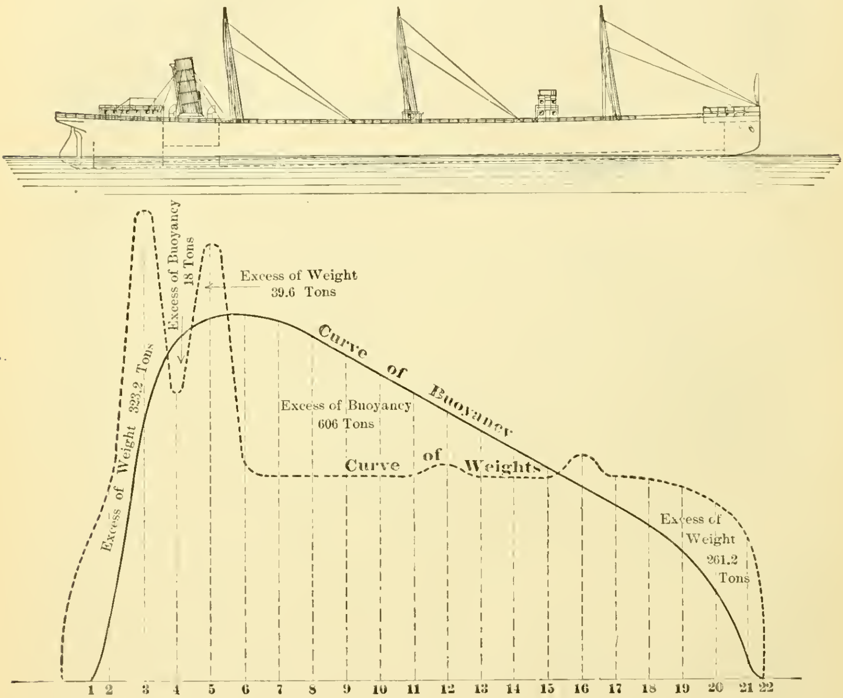


FIG. 1.

of to-day. There are many builders who are certainly building light ships, but are they such as redound to their credit and bring honorable mention to their firms? I regret to state that I believe that there are many boats now floating on the great lakes, built to satisfy the demands of the owner for great carrying capacity, in which the material is distributed in a far from efficient manner; and it will be only a matter of time when, owing to the intense working of the spar decks of these boats, the fatigue limit of the material will have been reached; and woe betide the owner who may have to pay the cost of stiffening the same! It is my firm

belief that with a better distribution of material we can obtain excellent results from our ships on a reasonable amount of material, and it will be my object this evening to endeavor to point out the little that has been done in this direction.

We all certainly appreciate the structural difficulty to be encountered when we increase the length of our present lake freighter from 432 to 475 or 500 feet, yet this feat will shortly become an accomplished fact. Before this could be carried out it was necessary to find some one who had the courage of his convictions and who would supply the money for such an undertaking. This gentleman was found in the person of Mr. John D. Rockefeller's representative, Mr. Bowers, general manager of the Bessemer Steamship Company, and his courage will, I have no doubt, be amply rewarded.

The two most important points to decide are (1) the "position of machinery," and (2) the "scantlings;" or, in other words, the "midship sections," that give the best possible distribution of material.

I. POSITION OF MACHINERY.

Figs. 1 and 2 illustrate a ship lying at rest in still water, unloaded. She has, therefore, to support only her own weight and that of her machinery. In Fig. 1 the machinery is placed aft; in Fig. 2 it is placed somewhat forward. Each figure shows two curves—the curve of weight and the curve of buoyancy. Owing to lack of time I have been unable to prepare similar curves for boats ballasted and loaded.

In Fig. 1, between ordinates 1 and 6, the curve of weight is in excess of the curve of buoyancy to the amount of about 345 tons; that is to say, this weight of 345 tons must receive support from some other part of the ship than that immediately under it. Between ordinates 6 and 15 the curve of buoyancy is considerably above the curve of weight, but between ordinates 15 and 22 the weight rises again in excess of the buoyancy to the extent of 261.2 tons. Our ship is simply a beam, supported amidships and weighted near the bow and near the stern with the weights of 261.2 and 345 tons, respectively. The result is a very severe bending moment in the area representing the excess of buoyancy.

In Fig. 2 the excess weight aft is 334 tons, and the excess weight forward is only 86 tons, while the excess of buoyancy amidships is only 420 tons. In Fig. 1 the center of gravity of the overhanging weight is somewhere about ordinate 3, while in Fig. 2 it is a little abaft of ordinate 5, so that, besides reducing

the unsupported weight, we have practically shortened our beam and consequently have reduced the bending moment around the center of gravity of the area representing the excess of buoyancy. Fig. 2 gives, therefore, a much better distribution than Fig. 1, which represents the old practice of placing the machinery in the stern, and it is also my belief that when the boat represented by Fig. 2 is ballasted the excessive vibration, or spring-board action observed in our modern freighters, will be no greater than in those already existing, notwithstanding her excessive length. I think,

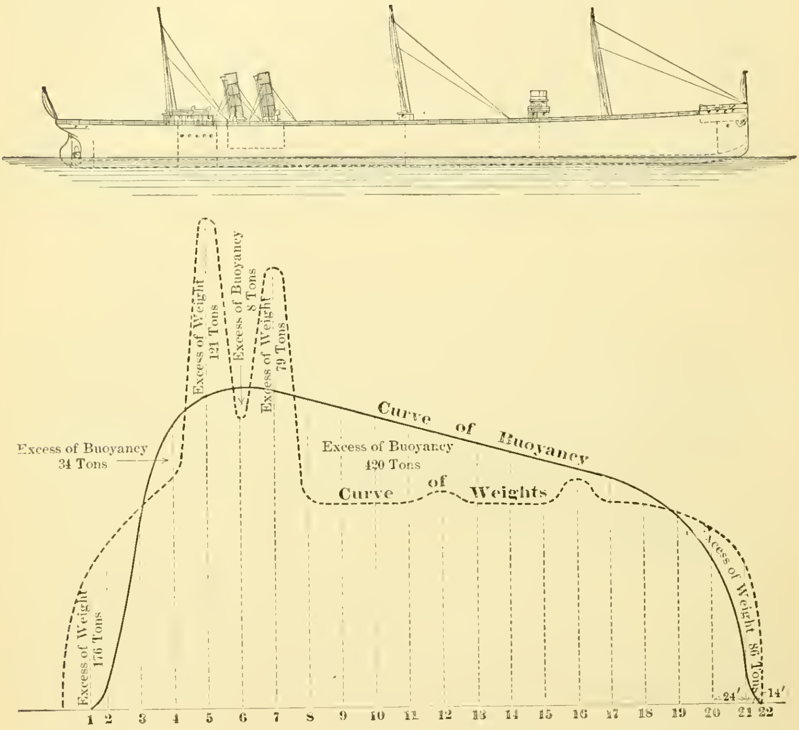


FIG. 2.

also, that this could have been still further improved upon had the machinery been placed further amidships; but it seemed advisable to stop where we did, in view of the difficulties that might possibly occur in handling the cargo over the tunnel which protects the line shafting. It was our intention to put a raised platform over the tunnel right across the ship, to facilitate, as far as possible, the handling of cargo. This, of course, would raise somewhat the center of gravity of the cargo placed aft.

I have here shown that, although a boat may be unloaded

and lying at rest, it is possible for her to be subjected to a very severe stress, and this stress might be either what is generally known as a "hogging" or as a "sagging" stress. In this particular case it happens to be a "hogging" stress; but it is possible, under certain conditions, to so distribute our weights, etc., that the boat will be subjected to a "sagging" stress, especially in heavily armored warships. Such a boat, loaded, and riding through a series of waves, would, in all probability, during a period of a few seconds and through each foot of its length, be subjected to a severe hogging and bending strain, due to the condition of support on the wave crest. The wave conditions on our great lakes are very difficult to approximate; at least, I have found it so during my endeavors to obtain reliable information concerning them.

II. MIDSHIP SECTIONS.

Fig. 3, design A, shows the "equivalent girder" for a given ship; that is to say, the material of the midship section is supposed to be collected and arranged in such form as will enable us to approximate the strength of the ship treated as a girder. The ship, whose equivalent girder is shown in Fig. 3, is one of several floating to-day on the great lakes.

Figs. 4, 5, 6 and 7 show the midship sections and the "equivalent girders" of four vessels, as follows:

Fig.	Design.	Vessels.
4	B	Schooners "Sidney G. Thomas" and "Antrim."
5	C	Steamship shown in Fig. 1.
6	D	Tow barge, consort to steamer shown in Fig. 1.
7	E	Steamship shown in Fig. 2.

The "Thomas" and the "Antrim" were built last spring by the Globe Iron Works Company—the "Thomas" for the Bessemer Steamship Company and the "Antrim" for the American Transportation Company. I consider the equivalent girder of the "Thomas" as embodying a great step in advance of her predecessors.

The boat represented in Fig. 5 is over 400 feet long, and has been steaming on the great lakes for a couple of years.

In the table, page 73, we find the moment of inertia of the several midship sections, and in comparing the bending moment of the latter we notice that, as we have progressed, we have so arranged our material that with each step the position of the neutral axis has been raised considerably. The benefit of this is apparent to all. On looking at the earlier equivalent girders,

the point that first strikes the observer is the very bad distribution of material. In analyzing a ship by this method, the first thing we should naturally do would be to map out for ourselves an ideal section to withstand the strains to which a ship is subjected; and I think our ideal would be the H section which is used so extensively for girders. Here we have symmetrical top and bottom members, practically uniform in section and securely attached or tied to one another by the center web. Now if we compare the equivalent girder of Fig. 3, design A, with this ideal girder, we find that there is no attempt to obtain equal sections for these two members, but that the bottom flange is excessively over-

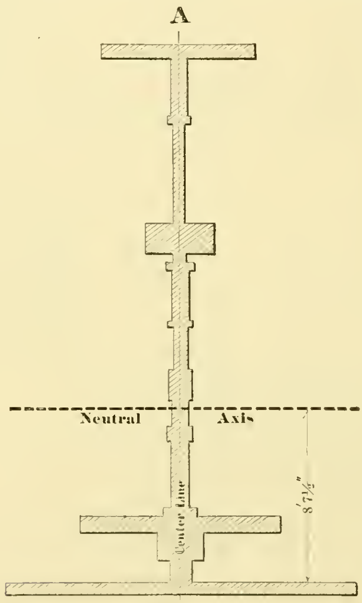


FIG. 3.
EQUIVALENT GIRDER, DESIGN A.

burdened with material, which consequently depresses the neutral axis of the whole section. In the equivalent girder of Fig. 4, design B, we note that, although the neutral axis has risen somewhat, we have, nevertheless, a girder far from symmetrical.

In Fig. 5, design C, we note a retrograde step. The neutral axis has not quite fallen back to the level of that in Fig. 3, design A, but very nearly so.

In the equivalent girders of Figs. 6 and 7, designs D and E, we notice a considerable improvement over the foregoing sections, and these represent what I believe to be the best and latest steps

taken in this direction. The top and bottom members of these beams show a more nearly equal distribution of material, and consequently quite a considerable rise in the center of gravity of their sections. The boats showing what I believe to be the best distribution of material have less material, relatively to their lineal dimensions, than those first mentioned.

In endeavoring to obtain these sections, our first thought was that Fig. 3, design A, showed an equivalent girder that was practically all bottom and altogether out of proportion with the top chord, the latter represented by the spar deck stringer and sheer strake. We have endeavored to take out quite a considerable weight from the tank, and have added this to spar deck and sheer strake, and in the shape of shelf plates under the spar deck beams and one, two or three longitudinal stringers running under the spar deck beams, and secured by intercostal plates to the spar deck as well. This material, when assembled, shows a very satisfactory section.

It will be very interesting to note that the boats represented by Figs. 6 and 7, designs D and E, have another distinguishing feature—the floors in the bottom are spaced every 2 feet, but the frames, from tank top to spar deck, are spaced 4 feet apart, and are made of a somewhat stronger section of channel than that generally adopted for this purpose. In addition, the top and bottom members are securely tied together by deep web frames, 24 feet apart, and also by 25-inch channel stanchions, 8 feet apart. Immediately under these stanchions are the bilge brackets, also solid, tying the top and bottom members together more securely. Of course, it would be considerably better if we could introduce also a system of diagonal bracing between these channel stanchions; but, inasmuch as this would affect the working of the cargo, it is out of the question. Owing to the increase in the spacing of the frames, the shell plating has not the local support that it had in earlier designs; but, taken as a whole, this structure, complete, is considerably stronger than that of the usual form. Recognizing, however, that the shell plating requires some additional support locally, we have introduced a system of longitudinal intercostals, built up of channel and so arranged that there is never more than a square piece of plate, 4 feet by 4 feet, unsupported. This channel, when worked into the ship, not only affords local stiffness, but, when properly fitted, can be made very effective and useful for hold stringers; and it will also be noticed that, in each case where we have introduced belt framing, we have also a deep floor rising from the bottom to the top of the tank, and

a much heavier channel forming the spar deck beam. This means particularly that the ship, every 24 feet, is held together both vertically and horizontally by a strong and most effective band, making what I believe to be one of the strongest, if not the strongest, midship section as yet on the lakes.

As before stated, in endeavoring to obtain some satisfactory information as to the wave conditions existing on these lakes, I failed to arrive at anything very definite. I have therefore had to assume conditions approximately; but I am satisfied that there

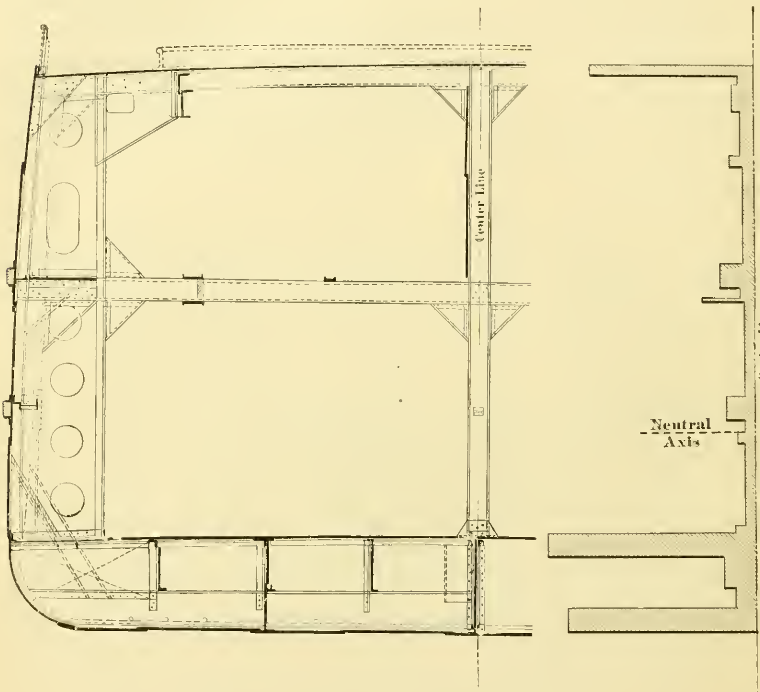


FIG. 4. DESIGN B.

are never less than three or four waves under even the shortest ship here illustrated. If this is so, it is fair to assume that all ships will practically, under the worst conditions, overhang a wave crest the same number of feet, and that the bending moment will therefore vary, not directly as the length, but in the ratio of this amount of overhang to the length of the ship. Fearing that some would think this was favoring the latter designs, I have given also a table showing a comparison of these several midship

sections, assuming that the aforesaid bending moment would vary directly as the length. In Table A, if we refer to design A, we shall notice that the stress in the top member, under these conditions, amounts to 11.1 tons per square inch, and in the bottom section 5.78 tons per square inch. In design B the 11.1 tons fall to 7 tons, and the 5.78 tons in the bottom member fall to 3.78 tons, which speaks highly for the midship section of B. In C, as before stated, we take a retrograde step. Here the stress in the top member rises to 9 tons per square inch, and in the bottom member to 4.86 tons; but when we come to D and E we see again a decided improvement. D has a stress of 6.48 tons per square inch in the top member and 4.77 tons stress in the bottom member, while E has 5.47 tons in the top member and 4.40 tons in the bottom member. That is to say, we have reduced the strain per square inch in the top member of the equivalent girder of E to one-half that of the top member of the equivalent girder of A, and have also slightly reduced the stress in the bottom member of E, as compared with that of A.

Now, if we take into consideration the value of the riveted seams, and assuming the same to be 75 per cent. of the solid plate, which I believe to be very high, we shall find our material in design A stressed to about 15 tons per square inch, and this means that the factor of safety is very low. In E we have a factor of safety practically twice that of A, assuming the material to be of equal value; but we know that open hearth steel, as used at the present time, is considerably better than that used some five or six years ago, and this will count greatly to the advantage of design E. Now let us refer to Table B, where, as before stated, we have assumed that the overhang and the bending moment will vary in proportion to the increased length. This, for the wave conditions obtaining on the lakes, will be placing the longer boats at a most decided disadvantage, compared with the smaller ones; but we find, on referring to the stress per square inch given in the table, that design A has the top and bottom members stressed 9 tons and 4.69 tons, respectively, and E has her top and bottom members stressed 7.25 tons and 5.88 tons, respectively, giving to D and E a decided advantage over those preceding, even under this unfavorable condition of comparison.

We certainly have here some food for reflection. These midship sections represent the practice of several years, and if we can justly come to the conclusion that we have made some little progress, it is certainly gratifying; and I think we are safe in assuming that the later practice represents a step forward. Tables A and

Table of Dimensions and Moments of Recent Lake Vessels.

TABLE A.

Fig.	Design.	Displacement, Net Tons.	Coefficient for Wave Crest.	Coefficient for Wave Hollow.	Bending Moment Foot-tons. Wave Crest.	Bending Moment Foot-tons. Wave Hollow.	Moment of Inertia.	Stress Tons per square inch. Top Member	Stress Tons per square inch. Bottom Member	Draft Mean. Ft.	Draft Mean. Ins.	Keel.	Beam.	M'l'd Depth.
3	A	1,600	30	45	53,580	35,720	79,694	11.10	5.78	5	9	....	....	....
4	B	1,770	37	50	78,420	52,850	175,555	7.00	3 78	4	7	366	44	26
5	C	2,800	40	60	90,011	60,007	184,803	9.00	4 86	6	0.5	412	48	28
6	D	2,703	43	62	102,166	70,857	268,122	6.48	4.77	5	6	436	50	28.5
7	E	3,400	48	68	98,839	69,769	288,670	5.47	4.40	4	6	455	50	29

TABLE B.

Fig.	Design.	Displacement, Net Tons.	Coefficient for Wave Crest.	Coefficient for Wave Hollow.	Bending Moment Foot-tons. Wave Crest.	Bending Moment Foot-tons. Wave Hollow.	Moment of Inertia.	Stress Tons per square inch. Top Member	Stress Tons per square inch. Bottom Member	Draft Mean. Ft.	Draft Mean. Ins.	Keel.	Beam.	M'l'd Depth.
3	A	5,358	37	50	43,443	32,148	79,694	9.00	4.69	17	0	....	....	....
4	B	7,220	37	50	71,420	52,850	175,555	7.02	3.78	17	0	366	44	26
5	C	8,739	37	50	97,309	72,009	184,803	8.26	4.46	17	0	412	48	28
6	D	10,076	37	50	118,733	87,862	268,122	7.54	5.54	17	0	436	50	28.5
7	E	10,427	37	50	128,224	94,885	288,670	7.25	5 88	17	0	455	50	29

B show this very distinctly, and, when we recognize that ship E is 43 feet longer than ship B, 2 feet more beam and 1 foot greater depth of hold, and has only about 100 tons more of material, we shall certainly recognize that we have made a most decided advance; and it is the ability to give to ship-owners these increased dimensions on proportionally smaller weight that renders this undertaking financially successful.

The figures given in tables A and B have been worked out on the slide rule; but they are, I believe, fairly accurate.

DISCUSSION.

Mr. Joseph R. Oldham.—I admire Mr. Newman's industry in producing such a paper as this. His diagrams are very interesting. There was one remark of Mr. Newman's, however, with which I do not agree; that is, relative to the weakness of our lake boats. At the present time we have not a "tin-pan" on the lakes, and certainly not one belonging to Cleveland. We have one or two thin boats, and I admit that they do not look very strong; but they have been gone over and greatly strengthened. I am told that we have some boats with very hard steel in them.

Speaking of the difference between buoyancy and weight, I think Mr. Newman is in favor of placing the engines aft. Now, as you are aware, the two ends of a vessel are not water-borne. When a vessel is in ballast there is no question that the engines are better at midships; but, when loaded, the strains are less severe with the engines aft. Vessels drawing 20 feet of water have greater stress of wave with the engines midship. Therefore, I am inclined to think that the engines are better aft. Mr. Newman thought that the tunnel would raise the cargo undesirably; but that is not so. There is no danger on lake vessels of having any cargo too high. I would ask Mr. Newman whether he took into consideration the arrangement of the butts, because there is a doubling plate, a shear plate and a stringer plate, and the butts are all together; whereas, when three butts are used they should be well separated.

A short time ago steel-makers made very hard steel, and when it was worked in the ships the steel broke. Then they said: "They say it is too hard. Let us make it soft enough to suit them." Are you sure the steel is not now too soft? Of course, this is a wonderful improvement in the equivalent girder.

I have never been able to see why a vessel that carries the boilers should not be as well riveted as the boilers. In boilers a man will arrange the pitch to a hundredth part of an inch, and

yet in a boat they think that anything will do, and are not at all particular to $\frac{1}{4}$ of an inch; yet $\frac{1}{4}$ of an inch in pitching a rivet will make a great deal of difference in the strength of the butts.

Our ships have the strongest bottoms afloat.

Mr. A. H. Raynal.—If the figures are correct, and if these diagrams are correct, we have only about 11 tons of strength (about 22,000 pounds) to the square inch. We can readily see that there can be a factor of safety of only $1\frac{1}{2}$; and if that be true,

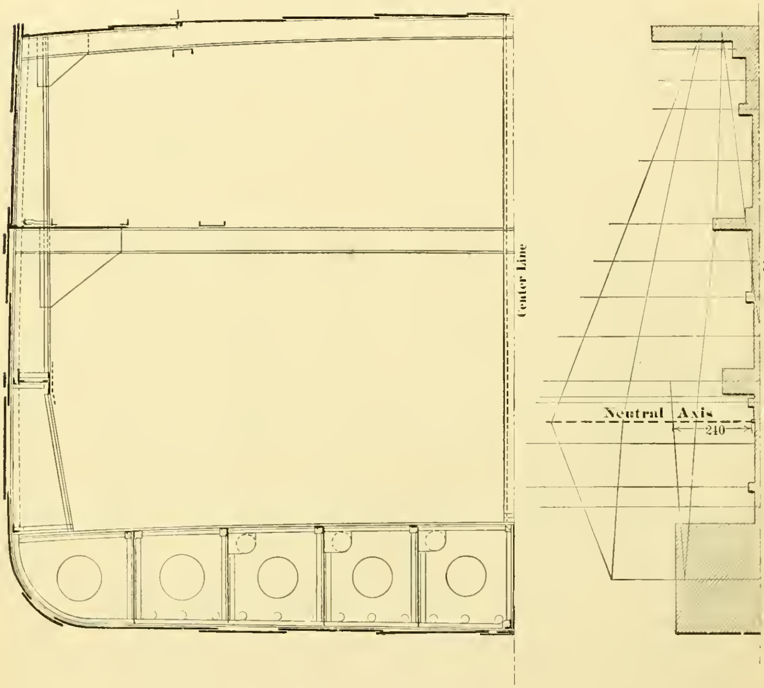


Fig. 5. Design C.

then that section of the ship is rather dangerously weak. If I understand Mr. Newman rightly, he is for taking the midship section of the H form.

Mr. John P. Johnston.—I desire to ask whether these diagrams of flotation represent the boats not loaded?

Mr. Newman.—Yes, sir; the boats are light.

Mr. Johnston.—Would there be any advantage in bringing the boilers forward and carrying the steam pressure back to the engines? It could be done without interfering with the bottom.

Mr. Newman.—No, sir; that would cut off the cargo space too much.

The President.—Captain Tuttle, will you tell us what makes these boats break in two once in a while? Is it because there is too much steel in them?

Capt. J. V. Tuttle (visitor).—The steel is not in the right place. I agree with all who have spoken, that it is an improvement to put the strength in the top. The ships which have broken had most of the strength in the bottom and not enough in the top. I can only speak practically of what I have seen, and I think it was lack of strength in the top, and not in the bottom, that caused them to break in two. There was metal enough, but it was not in the right place.

Mr. William B. Cowles.—It used to be the case that when a ship would pay for herself on the lakes in three or four seasons it did not pay to go into too fine points of economy; but now the traffic on the lakes is like what it is on the seas, and the fine points come in. It pays to look out for them, and to bring in some of the heretofore despised things that the salt-water people have been looking to for some time, for their profit. We shall have to put more scheming every year into this lake traffic. This is a right step in the right direction—improvement of details.

Mr. Oldham.—With regard to those vessels which have broken on the lakes (I can count seven, eight or nine), I have not known of one with wooden decks on top of the steel which has broken. It is quite the fashion to treat wood as valueless; but my theory is this: These steel-decked vessels did not break through tension; they broke through a hogging strain; and here the wood becomes of great use. A 3-inch wooden deck, to resist a hogging strain, is of more value than a 5-16-inch steel deck. It is quite the fashion now to talk of throwing the wooden decks away, but I am sure it will make a weaker ship. Compression always follows a sagging strain, and when the bow is immersed in the sea with the stern, then a sagging strain comes on and the ends are elevated. Then the wooden deck is of very good use. You cannot with impunity dispense with a wooden deck on top of a steel plate. The last steel deck I saw broken broke through the rivet holes. The rivet holes will assist a ship in taking compression as well as tension.

Mr. Newman.—Relative to Mr. Oldham's remarks respecting "tin-pans," I did not compare the vessels to a baking pan, but made the remark on the comparison of these figures in the chart. I would not like to sail on a boat knowing the conditions shown

in the diagrams to exist. My remarks concerning the engines were that, when the boat is in ballast, the engines midship would give better results than if placed aft. My remark about the cargo was not that we cannot carry the cargo too high, but that a high cargo in a quartering sea is apt to twist and wrench the hull.

Mr. Oldham's remarks concerning the riveting were possibly right. It is, no doubt, a fact that the bottoms of our lake ships

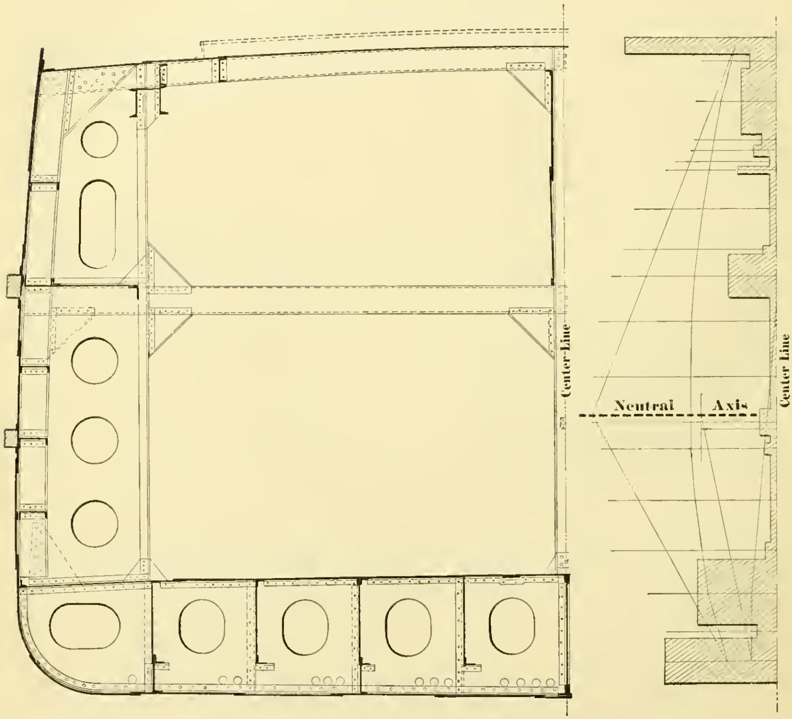


FIG. 6. DESIGN D.

are the strongest in the world; but if we put our trust in the bottom and do not look into the plating of the top, then, instead of being a source of strength, it becomes a source of weakness.

JOHN W. SEAVER (visitor).—Economy in the handling of material in the actual work of construction affects the cost of that work, though perhaps not quite so much as the distribution of material in the ship. Figs. 8 and 9 illustrate some changes which are now being made in two ship-building plants on the great lakes.

One plant (Fig. 8) is at the extreme end of Lake Superior, at the American Steel Barge Company's ship-yard.

The other plant (Fig. 9) is at the other end of the lakes, at the Union Dry Dock Company's yard in Buffalo.

In these two yards crane services are now being installed. They are of different designs, yet each, I believe, will effect a large saving in the actual construction of a ship.

This saving will be effected in the reduction of the labor required to transport the plates from the shop and yard to the side

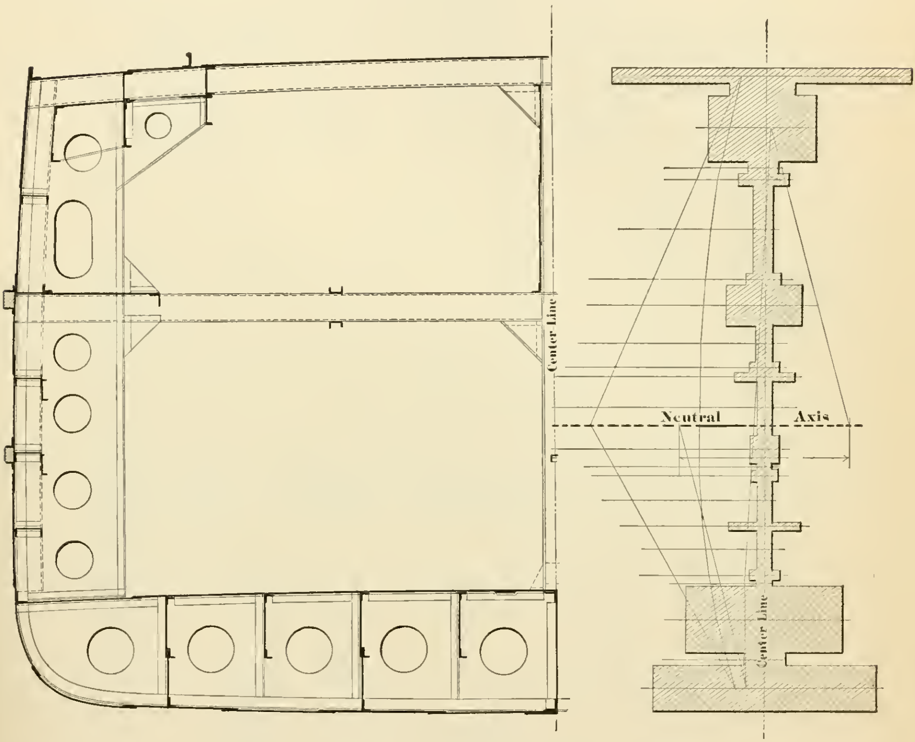


FIG. 7. DESIGN E.

of the ship, and hold them in position until they are properly secured with bolts.

The present practice in each of these yards is the same as in most of the other ship-yards in the country. A temporary staging is built each side of the vessel, and up inclined gang planks on this staging workmen drag the plates on small cars. This is a very laborious and expensive method of handling; and, considering the large saving of labor effected in the ordinary machine shops by means of the crane service, which is now a necessary equipment of

every modern shop, these two ship-building companies decided to install crane services over their yards.

Fig. 8 illustrates the crane and permanent scaffold which are now being erected for the American Steel Barge Company's shipyard. This crane is of the cantilever type and covers the berths for two ships.

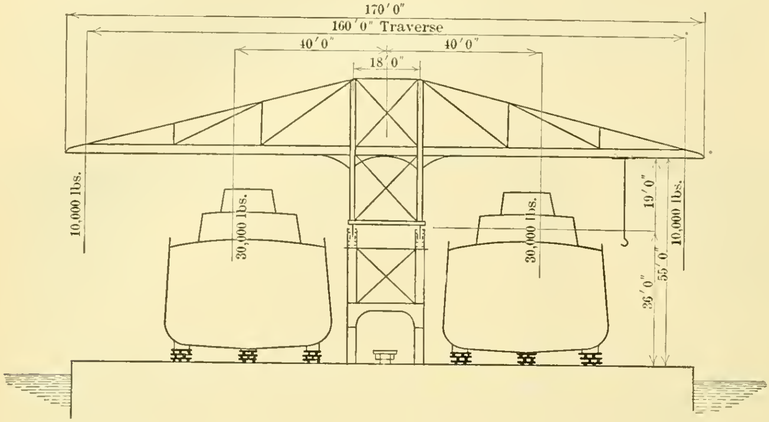


Fig. 8.
Crane Service for American Steel Barge Co.,
West Superior, Wis.

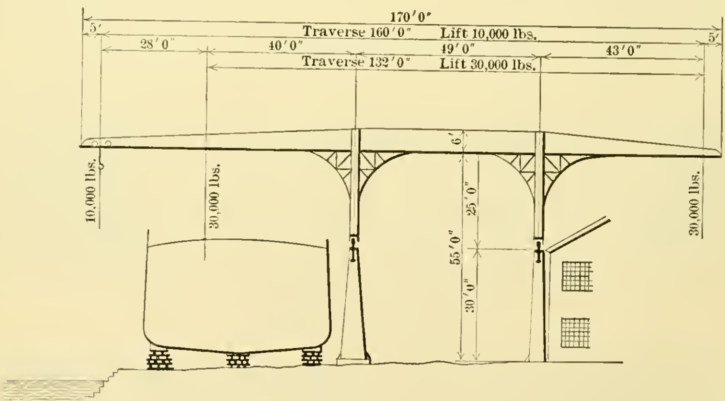


Fig. 9.
Crane Service for Union Dry Dock Co., Buffalo, N. Y.

The elevated steel track upon which the crane rests is utilized as a permanent scaffolding for one side of each ship. The material is brought from the punching shop on the small truck seen underneath this scaffolding and lifted up through the scaffolding and run out on one of the arms on either side of the crane to its posi-

tion over the ship. It is then lowered and held while being secured. This crane is to be a high-speed crane, having a velocity of 300 feet per minute on the runway, which will be some 420 feet long.

The service shown in Fig. 9 is now being installed at the Union Dry Dock Company's yard at Buffalo. This is a different type of crane and designed for a different service. Only one berth is covered; but the entire yard is served, and one arm extends over the punching shop, which may at any future time be removed, thereby giving an increased yard area covered.

The advantage of the second form of construction over the first is that less space is occupied in the yard by the runway, which, in this case, consists of two entirely independent lines of track.

This also is a high-speed crane. Both of the cranes are designed for continued and hard service, and are worked by electric motors of ample power to run them to their full capacity.

Mr. Newman.—In reference to these cranes, I think what Mr. Seaver has told us is very important, and I believe there is a great saving of labor in the application of these cranes; but it is difficult to get the money to put them in operation. I am only awaiting the money to put them in. I believe there would be a saving of 30 per cent. in the unskilled labor.

The President.—The yards at Lorain are equipped with cranes similar, except that they have a ship on each side of the main trestle, and outside of each ship a wooden trestle, which is readily taken down before launching a ship, and then replaced, the ship being launched sidewise, as is the custom here.

THE DIESEL MOTOR.

By Col. E. D. Meier, Member of the Engineers' Club of St. Louis.

[Read before the Society, February 2, 1898.*]

This motor represents the latest development in heat engines, and differs from almost all that have gone before in the manner of its evolution. It is not a result brought about by an accident, or by a train of thought begun with some other purpose and ending in discovery or invention. It is the direct and final outcome of a long course of study, begun with a definite purpose in view, that of producing a heat engine which shall approximate as closely as practicable to the ideal of Sadi Carnot.

Thermodynamics, like most sciences, grew out of the investigation and analysis of a number of practical experiments and practical results. Early inventors, therefore, knew nothing of the laws which they attempted to utilize. They were like travelers in some unknown and unmapped country, making discoveries in various directions, but unable to connect them or to understand their inter-relation. Such inter-relation, however, exists between the discoveries in the realm of science as well as in those made on an unknown plain or mountain range.

Thus each inventor follows out his own line to its farthest limits. The student and analyst come later, patiently separate the accidental from the essential, and, finding the underlying principles, combine them into a science, define the limits in each direction, and mark out new lines and new starting points for future inventors.

The Marquis of Worcester, when he forced water to the unprecedented height of 40 feet, or burst cannons by the explosive force of steam, in 1663, knew nothing of the equivalent in mechanical force of a given amount of heat. Huyghens in 1680, Papin in 1690, trying to produce motion and power through the explosive force of gunpowder, Savery in 1698, with the original pulsometer pump, Watt in 1769 harnessing the expansive force of steam, Street in 1791 exploding the vapor of turpentine in an engine cylinder, all essayed to utilize certain physical forces whose effects they had observed in various ways, but whose causes and limitations they were unable to analyze or measure. Therefore the development following the line of least resistance must proceed in the direction which for the time being presented the fewest obstacles or offered the most readily available means. It was

*Manuscript received February 9, 1898.—Secretary, Ass'n of Eng. Socs.

natural then that while gas and oil engines were being invented and developed alongside of the steam engine, that the latter should rapidly take the lead and leave behind it on every side the wrecked hopes of men whose intelligence and industry were fully equal to those of the early steam engine inventors, but who had unwittingly chosen the more difficult path. But nevertheless Street, Brown, Barnett, Drake, Barsanti, Matteucci, Lenoir, Beau de Rochas, Hugon, and others were working in the right direction and were building for the remote future, though incited by the hope of immediate results. Neither the materials of construction, the tools for manufacture, nor the science for intelligent direction were in their day available. For such pressures and such results as fully sufficed for the early steam engines, all these were at hand, and when greater pressures, greater velocities and more compactness were demanded the very industries the new motor had created, revived or extended kept pace with its development in the production of better material, more accurate tools and stronger machines for handling the heavier masses required.

It is well known that Watt was fully satisfied to evaporate a cubic foot of water each hour in order to obtain a horse-power, and that 8 pounds of good English coal burned under his boilers to produce this result was sufficient economy. The first improvements were directed to obtaining better packings, preventing leakages, improving valve motions and reducing frictions. While Woolf in Holland had early in our century shown in the great drainage system of his native country the advantages of the compound engine, the reason for its greater economy was not understood until much later. Even at the close of our civil war this was so little understood that a costly experiment on a large scale by a comparative dock test of the engines of the "Winooski" and "Algonquin" was undertaken by our Government. The eminent engineer Sickels contended that 12 and more expansions in one cylinder were possible, and would produce great economic results. Isherwood, to whom we owe the first conclusive experiment in cylinder condensation, opposed him with great abiltiy, but could not get intelligent public opinion on his side until he had, with four expansions, disastrously defeated Sickels with his twelve. Since then thermodynamics, nursed in the studies of Zeuner, Rankine, Clausius, and other men of genius, marched forth into the world and took possession of the designing room of all first-class engine works. From the compound engine were evolved the triple and quadruple expansion, intended by higher initial temperatures and less loss of heat in each cylinder to reduce cylinder condensation to its lowest limits; and latterly reheating of the exhaust from

the first cylinder on its way to the second is accomplishing this result to an extent sufficient to enable engine builders to dispense with the complications of the third and fourth cylinder.

Meanwhile the chemistry of fuels has been studied and developed, and the economy of the steam engine is now measured by the percentage of work it gives us in its main shaft as compared with the amount locked up as potential energy in each pound of coal burned on its boiler grates. We have thus by successive steps advanced from the 2½ per cent. efficiency of Watt to the 5 per cent. of the first-class modern slide-valve engine; from the 6½ to 7 per cent. of a good high pressure Corliss to the 10 per cent. of the perfect modern compound, and the 12 per cent. of the best triple expansion engines. With warning voices heard on all sides as to the increasing danger of the total consumption of the visible supply of fuel in the world, and with water wheels approaching 90 per cent. efficiency, with electric motors pushing them hard for first place, we must acknowledge that this result for the steam engine is not satisfactory, and yet it represents the cumulative result of the labors of thousands of engineers and mechanics, among them some of the most brilliant intellects that adorn the pages of the history of our race. There are, then, limitations against which the science of the analyst and the skill of the mechanic are vain. Or, let us say rather that both theory and practice have shown where these natural barriers are and point to a new direction for our energies.

Depending on the original heat value and the chemical and mechanical constitution of the coal, it is possible with the best of boilers and the best of management to put from 75 to 80 per cent. of the potential energy of the fuel into the boiler as steam. The balance of the enormous loss is generally charged to the steam engine, and on prima facie evidence this is just. The furnace and boiler have developed the heat from the coal and have stored up 75 to 80 per cent. of it in the steam space. But it is not in a condition to be entirely available for the purposes of the engine. Of the heat which has been put into the water in order to convert it into steam of the desired pressure and temperature, between three-quarters and two-thirds is necessary in order to change the form or physical condition of the water from the liquid to the gaseous state, hence only one-quarter to one-third of the heat which has been retained by the boiler is available for producing mechanical effect in the engine. Feed-water heaters and condensers save what they can of this large proportion. Of the 30 per cent. available we first lose a great deal in the transmission pipes. Experiments show that from 400 to 500 heat units are lost per hour per square

foot of pipe surface. By very carefully covering these pipes with non-conducting materials we can reduce this loss to one-third, but even then we have still a loss of 3 to 4 horse-power (known to be present in this steam) for every square foot. To put this in concrete form, consider a 100 horse-power engine requiring at least a 3-inch steam pipe, and we have a loss of 3 to 4 per cent. for every foot in length. Arrived at the cylinder, the condensation in the cylinder itself is the greatest enemy of economy. Actual measurements have shown 60 to 100 per cent. loss by condensation, *i.e.*, that 1.6 pounds to 2 pounds of steam had to be put into the cylinder to do the work of one. These are, of course, extreme cases, but they illustrate the great difficulties in the way of producing economy in the steam engine. And all these losses become greater as soon as the steam engine is to be used in cases where the work to be done is variable. For these losses in the pipe system, in cylinder condensation and by friction and radiation everywhere, are in the nature of fixed charges just as large when the engine is developing 100 horse-power as when it is developing 200. Naturally, then, the only chance for economy in the steam engine has been in the production of very large units where every precautionary measure, no matter what its first cost, can be employed in order to reduce to a minimum these great losses, and by the multiplication of the demands for power to make the variation less than it necessarily is in small plants. Besides this, for the larger engines, a higher degree of skill in the engineer in charge can be paid for, while the larger boiler units reduce the cost per horse-power in fireman's wages. Thus the concentration of power in one or a few large units in industrial establishments has added one more cause to the many which are driving the small shop and the small mechanic out of their independent position to become only so many cogs in the huge gearing of modern mass production. We may truly conclude, then, that the steam engine has nearly reached the limit of its possible perfection and usefulness, and that a better prime mover, capable of saving more fuel and of subdivision into smaller units, is the natural demand of the age. Rankine, Zeuner and Fleeming Jenkin have years ago predicted this, and some 300 firms and corporations actively engaged in building gas and oil engines are trying to supply this demand.

Following the partial success of Lenoir in Paris in 1860, and the further advance in 1867 of Otto and Langen in Cologne, came the invention of the Otto "Silent" engine in 1876, whose general method of action has been adopted practically by all subsequent gas and oil engine builders. Since the expiration of the Otto master patents, the development has been rapid in England,

as well as on the continent of Europe. All these engines are internal combustion motors. The fuel is burnt in the cylinder, thus saving all losses from radiation in furnace, boiler and pipe system, and utilizing the heat directly as produced in the working cylinder by expansion. The oil engine differs from the gas engine in having to change its fuel from the liquid state to that of gas or vapor before combustion. But the gas engine has to do this in a producer or retort of some kind placed at some distance from the engine itself, and is therefore subject to these losses. They may all be classed under four types.

First. Free piston engines, in which the work is not obtained directly from the expansion, but from the weight of the returning piston and the partial vacuum formed under it by the initial velocity due to explosion and expansion.

Second. Engines igniting at constant volume, but without previous compression.

Third. Engines igniting at constant pressure with previous compression, and

Fourth. Engines igniting at constant volume with previous compression.

Various difficulties, to which I cannot even refer in present limits, have tended to gradually eliminate all types but the fourth, and this works under the Otto method as the four-beat or four-stroke machine. The first stroke charges the cylinder with the explosive mixture at atmospheric pressure, the second compresses the charge to about 4 atmospheres, the third explodes it and permits it to expand doing work, the fourth expels the spent gases. Variations exist in methods of compressing and in methods of igniting. The ideal conditions of this cycle are very contradictory, one part of the cycle requiring what the other rejects. A happy medium is chosen from practical experience. It is found economic to keep the cylinder as hot as possible without endangering durability, generally at the temperature of boiling water. Some form of igniter is necessary. The earlier methods of gas jets passing through slide valves or alternately igniting in a hollow cock by an outside flame and being again blown out by the explosion within, have been entirely abandoned. Electric sparking is still used to some extent, but it is found to be uncertain unless sparks of considerable breadth can be obtained. Various kinds of chemical reaction have been tried, but discarded for want of durability in the elements used. The most generally used contrivance is the hot tube, heated up either by constant flame or by a rapid explosion, and into which the explosive charge is admitted at the beginning of each motor stroke. In the case of the oil

engine the vaporizer itself is found to be available as an igniting device. But self-ignition, as proposed by de Rochas as early as 1862, has never been attempted in practice for the simple reason that differences in the composition of the charge, in its temperature, and in the amount of compression, would vary the igniting point so that it might explode à long time before or after, instead of just after the beginning of the outward stroke, thus causing irregularity of action, loss of economy, and possible destruction of the engine.

This question of ignition of the charge is one sore spot in gas and oil engine practice; another is the question of regulation. It is not practicable to regulate by varying the amount of fuel injected, because a certain fixed proportion between the amount of air and the amount of gas or oil vapor is necessary to produce the true explosive mixture. A third difficulty is in the large clearance

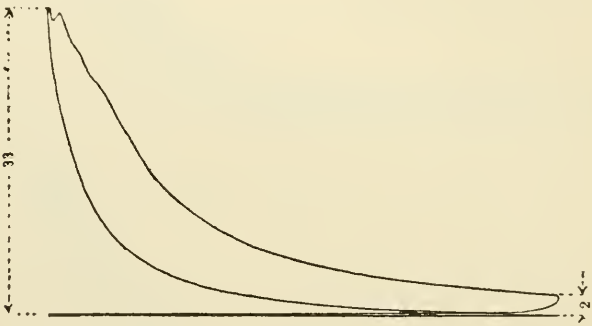


FIG. I. INDICATOR CARD, 20 H. P. DIESEL MOTOR, FULL LOAD.

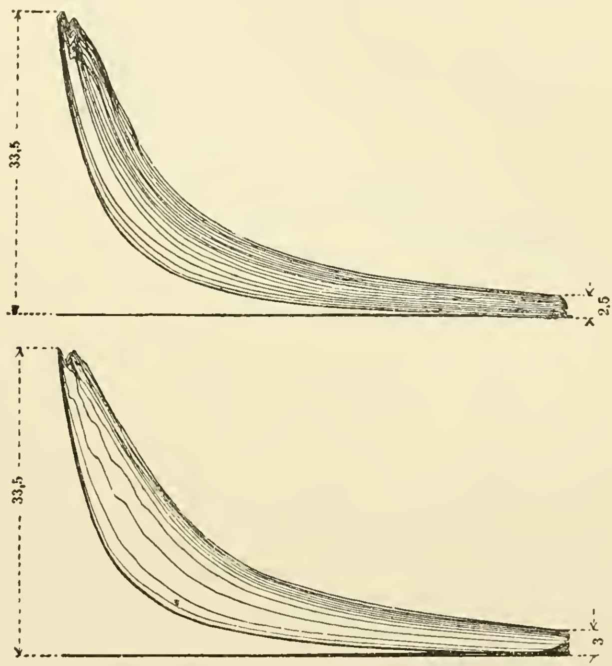
space necessary for containing the charge at its maximum compression and giving access to the ignition device. Most engineers need not be reminded of the evil effects of large clearances, and will realize that gas and oil engines must possess great virtues in every direction to be able to work successfully with clearance running up as high as 30 per cent. of the total cylinder volume, leaving only 70 per cent. for the working cylinder. Finally, the sudden action of all explosions, although somewhat modified by the imperfect mixture of the charge causing retarded combustion (the Nach-brennen of the Germans), causes such violent alterations of speed and pressure that very heavy parts, large fly wheels, and high speeds are necessary to approximate to the smooth-running of the steam engine. Thus, although gas motors have reached as high as 18 to 19 per cent. of actual brake efficiency, and oil motors as high as 16 to 17 per cent., so that small internal combustion

engines are showing better economic results than 1000 horse-power compound and triple steam engines, they are but slowly encroaching on the field occupied by steam. But they are gaining ground. There are some gas engine companies, each of which has sold in the last ten years from 90,000 to 100,000 horse-power, mostly in small engines of 4 to 6 horse-power each. Gas engines of 200 and 400 horse-power each have been built in limited numbers. Working between temperatures of 3000 degrees and 500 degrees, they approach Carnot's theoretical requirements more closely than the steam engine. But the higher degrees of temperature occurring during explosion are not utilized in Carnot's sense.

Most mechanical engineers in active practice to-day have met, in one way or another, the problems and the difficulties which I have lightly sketched, and finally had to shrug their shoulders and agree to do the best they could.

Rudolph Diesel, educated in thermodynamics by the great Linde, in close relationship with men like Zeuner and Schroeter, made this thermodynamic question the study of his life, and for 15 years devoted all his spare time and the savings resulting from a frugal life to the practical solution of the problem of the transfer of heat into work. Commencing with a full knowledge of thermodynamic requirements, his experiments were guided by a clear knowledge and a strong conscience which would not allow him to be carried away by partial success. The habit of merciless self-criticism has become so fixed in him and his knowledge of the possibilities of the rational motor is so clear, that nothing short of a large number of experiments and tests will satisfy him in regard to any new type or organ in connection with his heat engine. His short but conservative discussion of the problems published under the title of the "Theory and Construction of a Rational Heat Motor," and translated by Mr. Bryan Donkin into English in 1893, is familiar to most students of thermodynamics, and to those who can appreciate it, it is more fascinating than one of Stevenson's novels. As the doctors in thermodynamics do not agree on every point, his little book created much discussion. But brought to the attention of President Buz, of the Augsburg Machine Works, and of Friedrich Krupp, of Essen, by their consulting engineers, these far-seeing men were found willing to spend nearly a half million of dollars in developing this rational heat motor of Diesel's theory into a practical working machine. They placed Mr. Diesel at the head of a well-selected force of engineers, gave him a section of one of the large shops at Augsburg, in which to build, erect and experiment with his motor. The first 12 horse-power motor was gradually brought to a high state of efficiency,

and the experience gained embodied in a 20 horse-power motor which has since become the Kaaba Stone of the faithful among the mechanical engineers of Europe. With this motor to illustrate and prove his theories, Mr. Diesel, in April, 1897, read a short paper before a select circle of European engineers in Munich, and then took them to Augsburg to show and test the motor in their presence. So successful was this first public exposition that a large English firm at once bought the rights for Great Britain Mr. Diesel followed this by a more elaborate paper, read on June 16, 1897, before the Convention of Engineering Societies of Ger-



Figs. 2 and 3. Indicator Cards, 20 H. P. Diesel Motor, Variable Load.

many, at Cassel. He was followed by Professor Schroeter in a report on tests made by him on the Diesel engine. By this time the opposition and jealousy of the builders of older internal combustion motors had been aroused, and specialists were sent to Cassel for the express purpose of refuting and criticising Diesel. Like Saul of Tarsus they came back apostles of the new faith, and the largest gas engine companies of Germany, France and Belgium, recognizing the large and liberal-minded policy of Mr. Diesel and his associates, bought shop-rights and began either to

build Diesel motors in their existing shops, or to erect large shops for that special purpose.

I will not attempt to follow Diesel in his refined thermodynamical reasoning, or to offer any criticism of the same. The Cassel papers are now accessible in English, a translation having been first published by the "Progressive Age," in this country, and I have a limited number of copies in pamphlet form for those interested in the theoretical aspect of the matter. Most of you will be interested, as I am, in the practical side of the question. For them I will state first what I consider the underlying principle of Diesel's invention, and his great step in advance, and then give a short description of the motor as thus far developed.

Ignoring for the moment the patented mechanical details of the engine itself, Diesel's main invention is a *process* for converting the heat energy of fuel into work. It consists in first compressing air, or a mixture of air and neutral gas or vapor, to a degree producing a temperature above the igniting point of the fuel to be consumed, then gradually introducing the fuel for combustion into the compressed air, while expanding against a resistance sufficient to prevent an essential increase of temperature and pressure, then discontinuing the supply of fuel and further expanding without transfer of heat. This is then a process embodying in part the best of our steam engine methods. But Diesel, by using only permanent gases for the vehicle of the expansive force of heat, avoids cylinder condensation. He has less loss of heat to the cylinder walls, because again these gases have less conducting power than steam. The compression before admission, which we find so essential to the smooth working of the steam engine, he uses to a far greater extent. In fact, his upper limit of pressure is reached by the compression itself. Because even his combustion does not essentially increase his temperature or pressure, since it does mechanical work during its entire continuance, and after that during resulting expansion. The sudden blow on the piston which occurs even in the steam engine, and is unchecked and violent in all previous internal combustion motors, is entirely avoided by Diesel, for his adiabatic compression is gradual and complete. In place of the 30 per cent. of clearance in previous gas and oil engines, he has less than 7, and this small space is filled with air compressed to over 500 pounds pressure and at a temperature of over 1000 degrees. Into this the petroleum is slowly and gradually injected during a predetermined part of the stroke by means of compressed air, compressed by a separate air-pump to a temperature higher than that in the working cylinder. The result is a gradual and complete combustion, so that the exhaust of spent gases is noiseless, odorless and invisible. We have all of us noticed the puffing

noise and smell of gas or oil, the soot or the dripping of oil from the exhaust pipes of gas or petroleum engines. None of these exist in the Diesel motor. The exhaust pipe is in full view, close to a wall of cream colored brick, and runs just above the eaves of a slate roof. After running upwards of a year there is no discoloration on pipe, on roof or on the wall. In very damp weather a small quantity of steam accompanies each exhaust; in dry weather you see only a quiver of heat.

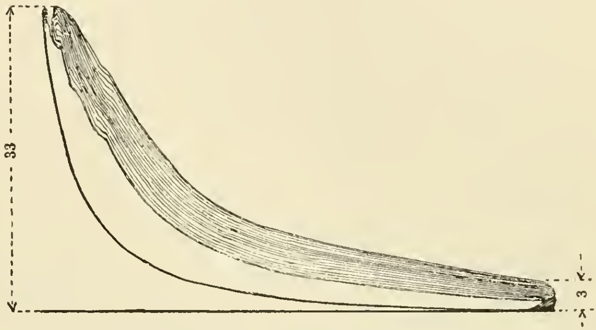


Fig. 4. Indicator Card, 20 H. P. Diesel Motor, Load Varying from Full to Half Load.

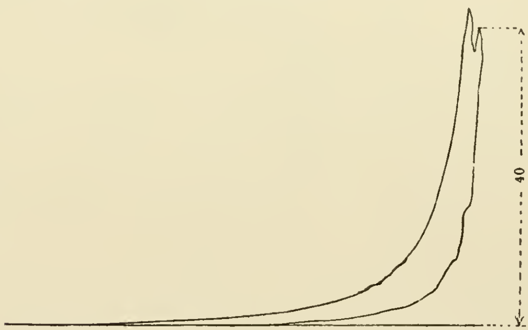


Fig. 5. Indicator Card from Air Pump, Diesel Motor.

The general construction of the motor is best shown in the sectional cuts which accompany this paper. In appearance it is like a vertical marine steam engine. Both main cylinder and air pump are single acting. The cylinder as well as cylinder heads are water jacketed. A small steel reservoir marked *b* is always kept supplied by the air pump to a pressure of about three atmospheres higher than that in the main cylinder. This air is used for injecting the petroleum during the working of the engine and after stopping is held in reserve by closing a stop-cock, to be used

in starting the engine the next day. This is accomplished by placing the crank just beyond the dead point, and by a lever throwing a cam into gear which opens a starting valve shown to the left in the section of the cylinder head. This being opened by a hand lever admits one full charge of compressed air, sufficient to cause one revolution; on the return stroke this starting cam is automatically thrown out of gear and the regular valve motion acts, and the first charge of petroleum is ignited at once, and in about 30 seconds the engine is under full headway. Once started the engine requires no attention except to see that the automatic oil cups are filled and act properly. The oiling of the main cylinder and of the air pump is done under pressure, the oil being forced in on the level of the lowest position of the upper packing ring. The consumption of petroleum of a low grade of lamp oil varies from 215 gms. to 250 gms. per brake horse-power. The amount of lubricating oil for an engine is considerably less than that for a good steam engine of equal power, and in the later engines a small cistern is provided in the base plate, into which all surplus oil flows through a filter, from which it is again pumped to the distributing tank from which small pipes carry it to the working parts.

The essential parts of the engine, after the cylinder and air pump, are the air induction valve c, the petroleum valve m, and the exhaust valve *d*. These are all located in the head of the cylinder, and only the surface of the valve head is exposed to the temperature of combustion.

When I saw the motor it had been running continuously for about 8 months. I had the three main valves removed and put my arm into the cylinder within 12 minutes after the last working stroke. It was not as hot as a steam cylinder under similar conditions; was worn perfectly smooth; there was no soot or crust in the combustion chamber. The heads of the valves being cooler, had accumulated just enough soot to blacken the fingers in wiping it off. But underneath this the surface was smooth and polished, except a few rust spots on the head of the air valve. These valves are made of hammered steel. The cylinders are made of close-grained cast iron, with a little admixture of wrought scrap, steel castings having been found too porous. The engine was shut down in my presence, at the request of a commission of engineers from Vienna and Stuttgart, and in conjunction with them I spent one hour and a half in a critical examination of all the working parts. From conversation and considerable questioning of the machinist in charge, I judge that there has been practically *no* cleaning of the internal parts done since the motor was first started in October, 1896. No soot or crystallized carbon can form any-

where, because the combustion is perfect and complete. These earlier engines show many complications, just as all new machines do. As Mr. Marx, the chief engineer of the steam engine department of the Nürnberg Works, remarked, when we practical men get to building them by the quantity we will eliminate all these useless trappings, and in a year or two we will have as simple a machine as any steam engine. But as high pressures and high temperatures (though much lower than those of other internal heat engines) must be used for the successful work of these motors, only the best of material and the best of workmanship can be employed. As compared to the best modern gas and oil engines, the Diesel engine shows a great advance in economy, while at the same time giving a smoothness of action heretofore reached only by the best steam engines. Furthermore, its loss in efficiency when running at half-load is also considerably less than that of gas or oil engines. Its regulation is perfect. The cylinder always compresses a full charge of air, so that there is always a surplus to burn the fuel injected, and there is no necessity as in explosion engines for preserving the exact relations between the quantities of air and fuel. The thermic efficiency is greater when the charge is reduced, so that it largely covers the greater per cent. of loss in the mechanical efficiency, which as we have seen always occurs at less than normal load, because the quantity is fixed.

Since Mr. Diesel began his work with the fixed determination of finding something worthy of supplanting and succeeding the steam engine, the question is pertinent, Will this motor do so? Were we to consider only the economy in fuel, there could be but one answer. For, while the best steam engine gives us but 12 per cent. efficiency, the best oil engine from 16 to 17, and the best gas engine but 18 to 19, all figured from the actual heat energy in the coal or oil to the actual brake horse-power, the Diesel motor began with 25 per cent., has shown from 26 to 29 on many tests, and has sometimes reached 30 per cent. Furthermore, for American conditions this high efficiency has been practically maintained when running with such residual products as gas oil or fuel oil. But there are many other conditions. First comes availability at all times and places, and simplicity. The simplicity of the steam engine for small powers has been the result of judicious elimination of parts, in many cases accompanied by some sacrifice in fuel economy. There are many thousands of cheap steam engines running to-day which do not utilize 1 per cent. of the fuel expended on them. They are used for the same reasons that saw millers persist in buying and using old steamboat boilers which have been thrown out by inspectors as dangerous. There is a very

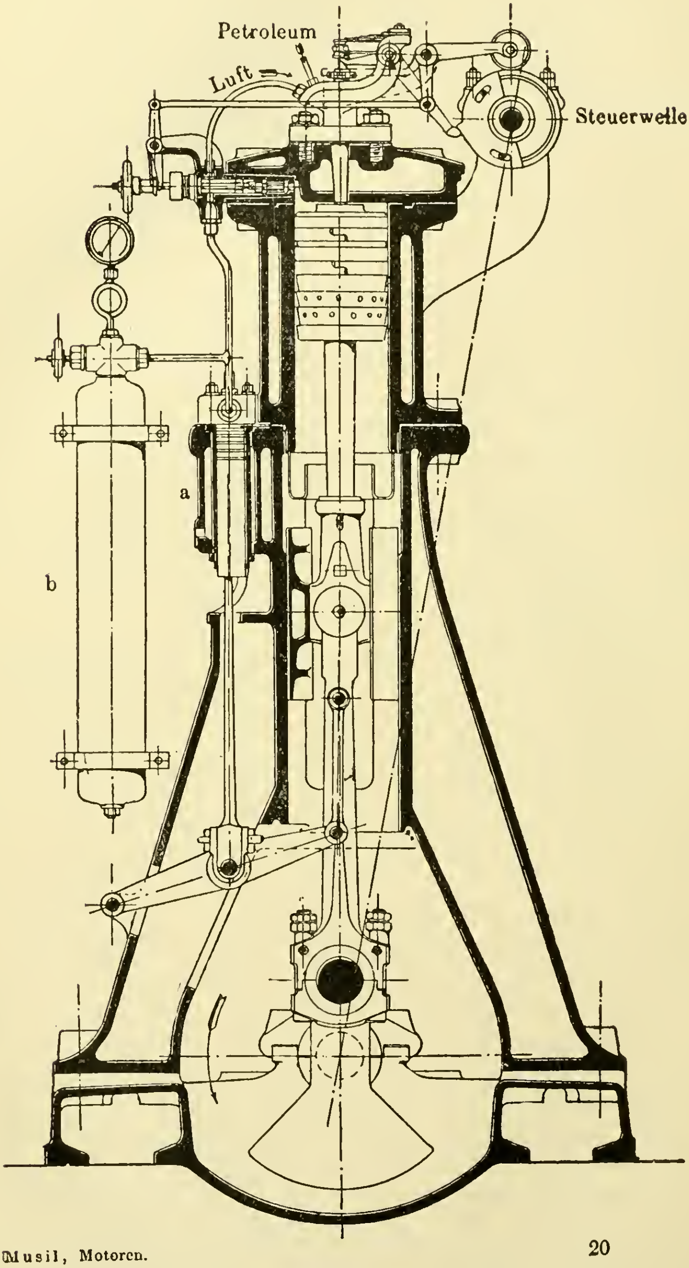


FIG. 6.

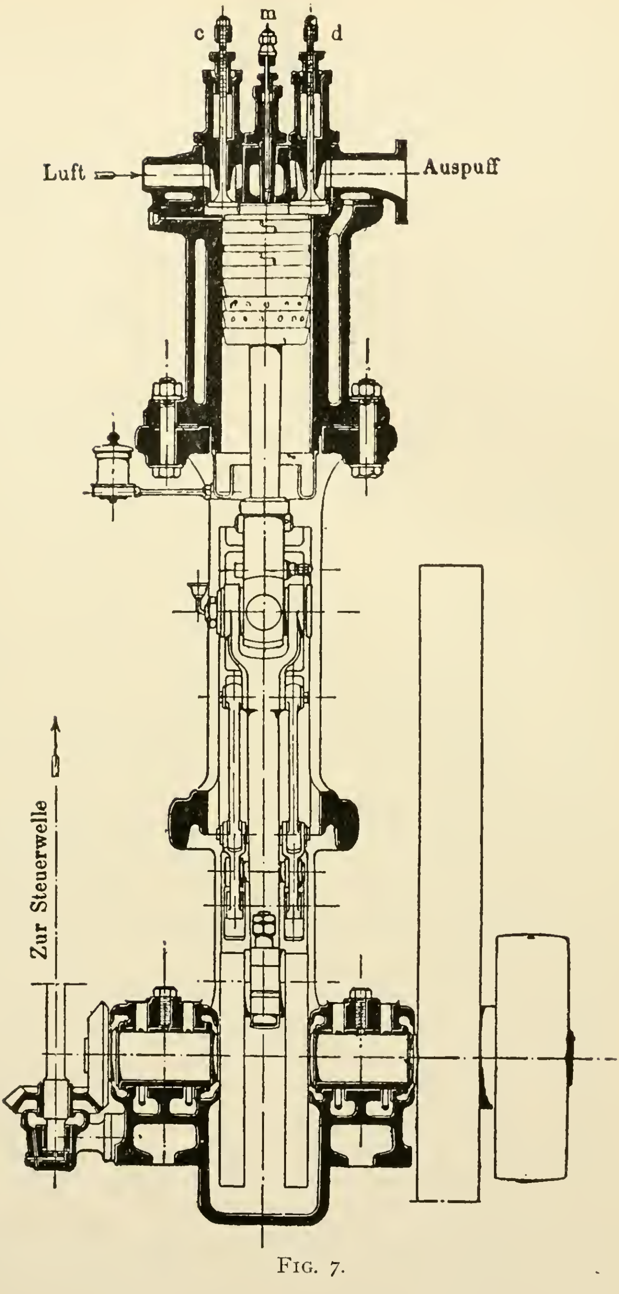


FIG. 7.

wide-spread belief that any tramp picked up for harvesting on a farm can run a small steam engine, and although this belief results in a somewhat rapid diminution of that class of labor, it has not yet been recognized as a superstition.

Where coal is as abundant and cheap as in the United States, the first cost of any fuel-saving device militates strongly against its adoption; only in large establishments, notably electric light and power plants, water works, flour mills, the more modern blast furnaces and steel works, and in some breweries is economy of fuel recognized as essential, and in comparatively few of these is it watched as it should be. But the tendency to watch and scrutinize all the outgo in these various plants is growing. The enormous development of the electric industries, and the necessity of cheapening the cost of the current, so as to compete on more even terms with gas, has led to a more general and careful scrutiny of the cost of a steam horse-power than was ever before attempted. While a great many devices have been introduced whose only merits are the first expert duty test and the never-failing eloquence of their promoters, a great many improvements have been made and plants more carefully designed, making continued economy probable. The most notable feature of these improvements is the sweeping away at once of all those auxiliary machines, formerly thought necessary, which are known by the expressive title of "steam chewers," and replacing them either by machinery directly connected with the main engine or running by electric motors.

A recent careful investigation of the cost of auxiliary steam power on board the United States Steamship "Minneapolis" shows some of the auxiliary engines using as high as 266 pounds of steam per indicated horse-power hour, and a number of others running up to 100 and 125 pounds per indicated horse-power hour, or, roughly speaking, the auxiliaries are shown to have an efficiency of less than one per cent. As all these auxiliaries can be, without the slightest difficulty, run by Diesel motors, it is fair to presume that here is a field in which the Diesel motor will almost immediately supplant the steam engine. In regard to the main steam engines of steamships, locomotive engines, street railway motors, and motors for automobile carriages, the substitution of the Diesel motor for the various forms now employed, whether direct steam or electric, by overhead or underground trolley, seems not only desirable but so imperative a necessity as to scarcely leave time for that careful development of types for these special purposes which must precede their general introduction. Leaving out of question the wasteful engine of locomotives or dummy cars, and considering the triple expansion marine engine only, we have this comparison:

The marine engine will, under fair average conditions, show as high as 10 per cent. efficiency; allow that, under like conditions of hard service, the efficiency of the Diesel motor drops as low as 25 per cent. Remember further that we have in the fuel oil 1.4 times as much calorific value per pound as in good bituminous coal, and we have 1.4x2.5=3.5 times as much power in each pound of fuel oil carried for the Diesel motor as in each pound of coal carried for the steam engine. We have from this alone a saving in dead weight of over 70 per cent. To this must be added the saving in weight of boilers with the water contents, of stored fresh water, and of the evaporators. I am allowing that the multicylinder Diesel motors will weigh as much as the present engines with their pumps and condensers. Besides, there is the enormous saving in the labor of stokers, which will not be needed with Diesel motors.

It will, of course, be some time before large marine motors will be successfully built, but the first one of 400 horse-power has been planned in England, and as soon as certain preliminary experiments have been completed, its construction will be begun and no doubt pushed rapidly.

For street car and railway car work there are two motors building in Nürnberg at the present day, and the successful development of that type may be confidently hoped for during the year.

Experience shows that in all electric light, and to a slightly less degree also electric power plants, there will recur sudden abnormal demands whose time cannot be predetermined, and for which provision must be made. This means either holding an additional boiler under steam, or for a short period forcing the boilers already in service to nearly double their normal work. For such purposes a number of Diesel motors, each directly coupled to its own dynamo will be invaluable. What manager of an electric power plant would not feel more at ease if he had a number of such motor units, say of 60 to 100 horse-power, each ready for full service in 30 seconds from the time notice of the sudden demand is given? In existing electric railway plants the ability to save a large investment in copper for lightly-traveled, long-distance suburban roads, and to run owl cars without using the main engine, will also open a field for the Diesel motor. In deep mines, frequently at a distance from the coal supply, in portable pumps and drainage plants, and in large placer mining districts where water is scarce, similar conditions exist as explained for the marine engines, and the first Diesel motor successfully run in any such field will probably bring a demand larger than can be promptly supplied.

As regards the probable cost of running Diesel motors, careful

comparison for German conditions has been made by the Augsburg Machine Works. Being large builders of steam engines themselves and having built and run now several different sizes of Diesel motors, their figures may be relied on. In making the comparison they allow 10 per cent. on the first cost of the machinery and 5 per cent. on the cost of buildings for interest and depreciation. They find that a 30 horse-power single-cylinder condensing steam engine consuming 26.5 pounds per effective horse-power hour, costs 1.81 cents per hour. This includes interest, wear and tear, supplies, fuel and labor. A single cylinder Diesel motor, charged with the same items, will cost 1.08 to 1.30 cents per effective horse-power hour, according to local conditions and kind of oil used.

A 50 horse-power tandem compound condensing steam engine, requiring 20 pounds steam per horse-power hour, will cost with the same items 1.44 cents per effective horse-power hour, and a 2-cylinder Diesel motor plant to supplant it only 1.03 to 1.17 cents, according to locality and kind of oil.

In these figures the fuel cost is about 50 per cent. of the total for the steam engine and 47 per cent. for the Diesel motor. It must be remarked, however, that in this calculation the price of the Diesel motor is arbitrarily fixed much higher than actual cost, in order to bring it near the first cost of the steam engine with its boiler plant. I find that in these figures the coal was taken at about $6.00 per ton, and the petroleum at from 6.6 cents to 9.3 cents per gallon, *i. e.*, the fuel cost is over three to four times that of American conditions. As corroboration of these figures, I have received, from an experienced engineer in Nürnberg, a similar calculation comparing a 20 horse-power high-pressure steam engine with a 20 horse-power Diesel motor running, respectively, 2.35 cents and 1.79 cents per effective horse-power.

I am not at present prepared to give complete figures of comparison between a Diesel motor and various types of steam engines in this country, for I have not yet sufficient data to bring into the comparison the first cost of the plants. But so far as fuel cost is concerned, I can give a comparison with tolerable accuracy, based on local conditions, viz: Illinois coal, $1.10 per ton delivered, and fuel oil at 2 cents per gallon delivered in tank cars or tank wagons. In this I am taking average results on a 20 horse-power Diesel motor. For larger sizes the mechanical efficiency of the motor will be much increased, and hence with the same thermic efficiency the commercial economy will be somewhat better than the present actual figures on which I base the comparison. The cost of 100 actual horse-power per hour in fuel will be 30.3 cents for a plain

slide-valve engine; 24.2 cents for the plain Corliss engine; 12.43 for the triple expansion engine, and 15 cents for the Diesel motor. As no one is likely to build a triple expansion engine for 100 horse-power, we must consider this as a proportionate amount based on the performance of a triple expansion of say 1000 horse-power. It would be fair, therefore, to add to these figures, for fuel, about one-half the hourly cost of the fireman in the case of the small engines, and one-quarter in the case of the triple engine. In this way the total would stand respectively per 100 actual horse-power per hour, 40.3 cents for the slide valve, 34.2 cents for the Corliss, and 17.43 for the triple expansion engine, as against 15 cents for the Diesel motor.

For the better grades of Eastern coal, at an average price of $2.80 per ton, and remembering that only .7 as much coal will be used, we would have, respectively, 54.5 cents for the slide valve, 43.5 for the Corliss, and 22.4 for the triple expansion, as against 15 cents for the Diesel motor. And if we make the same allowance for the proportion of firemen's wages, the figures will stand 64.5 cents for the slide valve, 53.5 for the Corliss, 27.4 cents for triple expansion, and 15 cents for the Diesel motor. Of course, to these figures the interest on investment and wear and tear should be added. They will, however, make the comparison more favorable for the Diesel motor, for the first cost will be a great deal less than that of the steam engine, with boilers, furnaces, smokestacks, pipe work and boiler house. Hence the interest account will be lower; so far as wear and tear are concerned that will certainly be greater for the steam engine when we consider the grate and furnace repairs of the boilers and the occasional renewals of iron smoke-stacks. I prefer, however, to merely mention these items, confident that a few years' experience with Diesel motors will give us even better figures than it would be fair now to anticipate.

I am confident therefore that the Diesel engine will in the course of time gradually supplant the steam engine. Its builders will, of course, make use of the vast amount of valuable experience, experiments and scientific investigation represented in concrete form by the best steam engines of to-day. Diesel motors will be built best by those who to-day build the best steam engines, and it is certainly in the interest of the owners of the Diesel patents that only first-class Diesel motors shall be built.

The original owners of the Diesel patents, viz: Messrs. Rudolph Diesel, the Augsburg Machine Works, and Friedrich Krupp, fully appreciated this and determined to bring the best constructive talent, the best workmanship, and the best manufacturing facilities to bear on the rapid and complete development of this new motor.

They therefore inaugurated in the beginning a broad and liberal policy of reciprocity. They agree to a prompt and complete distribution to all licensed builders of every fact, experience and experimental result, all drawings in every detail and all improvements that may emanate from any one shop, to all the others.

At present there are seven large shops licensed in Germany, one each in France, Belgium and Switzerland; two in Denmark, and one in England, so that each one of these gets data from twelve others. The immense value to each firm in thus getting the results of all experimental work from the others without the cost in time and money of making them for itself, will be appreciated by every engineer who has ever had to develop any new industry or machine. Imagine the great amount of money that would have been saved to this country if the Corliss patents could have been in the beginning thus made accessible to all first-class engine works, instead of compelling them to try to compete against these superior devices with all that array of balanced slide valves, piston valves, and the numberless jimcracks which promptly found their way to the scrap pile as soon as the Corliss master patent became public property. Of the 13 European licensees, 8 are well known steam engine works, 3 gas and oil engine works, and 2 entirely new companies. One of these works is making a cash investment of $600,000, and another one of $300,000 in shops and machinery to build Diesel motors exclusively. Many other engine works, whose names it would not be proper to mention until the contracts are closed, are now negotiating for licenses in Europe.

These facts answer the question as to whether the Diesel motor will in due time supplant the steam engine. Certainly our European colleagues believe that it will. In America, of course, the conditions are different. Our fuel is much cheaper and more abundant, and we are less inclined to economize in that item. But our labor is much higher, and, as the labor account shows a large balance in favor of the Diesel motor, I see no reason why, with natural development of type after type, the Diesel motor will not obtain the lion's share of the work now done by the steam engine.

ASSOCIATION OF ENGINEERING SOCIETIES.

Articles of Association.

The following Articles of Association were adopted at a meeting held in Chicago, December 4, 1880. At this meeting there were present representatives of the

Western Society of Engineers,
Civil Engineers' Club of Cleveland,
Engineers' Club of St. Louis,

and the

Boston Society of Civil Engineers

was represented by letter.

For the purpose of securing the benefits of closer union and the advancement of mutual interests, the engineering societies and clubs hereunto subscribing, have agreed to the following

ARTICLES OF ASSOCIATION.

ARTICLE I.

NAME AND OBJECT.

The name of this Association shall be "The Association of Engineering Societies." Its primary object shall be to secure a joint publication of the papers and the transactions of the participating Societies.

ARTICLE II.

ORGANIZATION.

Section 1. The affairs of the Association shall be conducted by a Board of Managers under such rules and by-laws as they may determine, subject to the specific conditions of these articles. The Board shall consist of one representative from each Society of one hundred members or less, with one additional representative for each additional one hundred members, or fraction thereof over fifty. The members of the Board shall be appointed as each Society shall decide, and shall hold office until their successors are chosen.

Sec. 2. The officers of the Board shall be a Chairman and Secretary, the latter of whom may or may not be himself a member of the Board.

ARTICLE III.

DUTIES OF OFFICERS.

Section 1. The Chairman, in addition to his ordinary duties, shall countersign all bills and vouchers before payment and present an annual report of the transactions of the Board; which report, together with a

synopsis of the other general transactions of the Board of interest to members, shall be published in the Journal of the Association.

Sec. 2. The Secretary shall be the active business agent of the Board and shall be appointed and removed at its pleasure. He shall receive a compensation for his services to be fixed from time to time by a two-thirds vote. He shall receive and take care of all manuscript copy and prepare it for the press, and attend to the forwarding of proof-sheets and the proper printing and mailing of the publications. He shall have power, with the approval of any one member of the Board, to return manuscript to the author for correction if in bad condition, illegible, or otherwise conspicuously deficient or unfit for publication. He shall certify to the correctness of all bills before transmitting them to the chairman for counter-signature. He shall receive all fees and moneys paid to the Association and hold the same under such rules as the Board shall prescribe.

ARTICLE IV.

PUBLICATIONS.

Section 1. Each Society shall decide for itself what papers and transactions of its own it desires to have published and shall forward the same to the Secretary.

Sec. 2. Each Society shall notify the Secretary of the minimum number of copies of the joint publications which it desires to receive, and shall furnish a mailing-list for the same from time to time. Copies ordered by any Society may be used as it shall see fit. Payments by each Society shall in general be in proportion to the number of copies ordered, subject to such modification of the same as the Board of Managers may decide, by a two-thirds vote, to be more equitable. Assessments shall be quarterly in advance, or otherwise, as directed by the Board.

Sec. 3. The publications of the Association shall be open to public subscription and sale, and advertisements of an appropriate character shall be received, under regulations to be fixed by the Board.

Sec. 4. The Board shall have authority to print with the joint publications such abstracts and translations from scientific and professional journals and society transactions, as may be deemed of general interest and value.

ARTICLE V.

CONDITIONS OF PARTICIPATION.

Section 1. Any Society of Engineers may become a member of this Association by a majority vote of the Board of Managers, upon payment to the Secretary of an entrance fee of fifty cents for each active member, and certifying that these Articles of Association have been duly accepted by it. Other technical organizations may be admitted by a two-thirds vote of the Board, and payment and subscription as above.

Sec. 2. Any Society may withdraw from this Association at the end of any fiscal year by giving three months' notice of such intention, and shall then be entitled to its fair proportion of any surplus in the treasury, or be responsible for its fair proportion of any deficit.

Sec. 3. Any Society may, at the pleasure of the Board, be excluded from this Association for non-payment of dues after thirty days' notice from the Secretary that such payment is due.

ARTICLE VI.

AMENDMENTS.

These articles may be amended by a majority vote of the Board of Managers, and subsequent approval by two-thirds of the participating Societies.

ARTICLE VII.

TIME OF GOING INTO EFFECT.

These articles shall go into effect whenever they shall have been ratified by three Societies, and members of the Board of Managers appointed. The Board shall then proceed to organize, and the entrance fee of fifty cents per member shall then become payable.

These articles were adopted by the several Societies upon the following dates:

Engineers' Club of St. Louis, January 5, 1881.
Civil Engineers' Club of Cleveland, January 8, 1881.
Boston Society of Civil Engineers, January 19, 1881.
Western Society of Engineers, April 5, 1881.

The Board of Managers was organized at Cleveland, January 11, 1881.

The following Societies have since certified their acceptance of the Articles, and have become members of the Association of Engineering Societies:

Engineers' Club of Minneapolis, July, 1884.
Civil Engineers' Society of St. Paul, December, 1884.
Engineers' Club of Kansas City, January, 1887.
Montana Society of Civil Engineers, April, 1888.
Wisconsin Polytechnic Society, June, 1892.
Denver Society of Civil Engineers, January 24, 1895.
Association of Engineers of Virginia, February 1, 1895.
Technical Society of the Pacific Coast, March 1, 1895
Detroit Engineering Society, January, 1897.
Engineers' Society of Western New York, January, 1898.

The Wisconsin Polytechnic Society withdrew from the Association in March, 1894.

The Western Society of Engineers withdrew in December, 1895.

The Engineers' Club of Kansas City disbanded at the close of 1896.

Annual Report of the Chairman of the Board of Managers.

Boston, December 31, 1897.

To the Members of the Board of Managers of the Association of Engineering Societies:—

Gentlemen:—In compliance with the provisions of our Articles of Association, I have the honor to submit the annual report of the Chairman for the year 1897. The very full report of our Secretary, herewith transmitted, shows the condition of the affairs of the Association so clearly as to leave but very little for the Chairman to say.

The Association is certainly to be congratulated upon the present state of its finances. For the first time in its existence, there is in its treasury a working capital sufficient to meet any ordinary demand, and to enable all bills to be paid promptly; and this condition has been brought about at the same time that a substantial reduction has been made in the rate of the annual assessment. The total assessment for the year 1897 was less than that for any previous year since the organization of the Association, and I can see no reason why for the coming year it should not be still further reduced.

If the members of the several Societies will interest themselves in the matter of securing advertisements for the JOURNAL, either personally or through a committee appointed for the purpose, I am confident that the annual assessment can be made less than $2.00 per member, and this without impairing in any way the present excellent condition of our publication. During the past year but $417.50 have been received from advertisements, as against $858.00 in 1896. This is a very serious falling off, and I would urge upon each member of the board the importance of bringing the subject before the Society which he represents. The officers and members of the several Societies are in position to judge as to the lines of business in their immediate vicinity which would be benefited by advertising in our JOURNAL, and there is no better way in which a member can aid his Society pecuniarily than by procuring a liberal amount of advertising matter for the JOURNAL, and by this means reduce the assessment which his Society pays to the Association.

In addition to the election of officers, the only business which the board has been called upon to transact during the year has been in connection with the issuing of five extra copies of the JOURNAL to each member of the board. In November last you voted to discontinue this practice and adopted the following rule: The Secretary is authorized to send *gratis* to any Society in the Association as many copies of each issue of the JOURNAL as it shall notify him it desires, not exceeding five (5) copies for each representative it has on the Board of Managers.

I desire to congratulate the members of the Association upon having secured for another term the services of our efficient Secretary, Mr. John C. Trautwine, Jr. To him the Association is very largely indebted for the very satisfactory condition in which we find our affairs at the close of the present year, and to his able management during the past four years belongs the credit for the present prosperity of our JOURNAL. The small salary which we have been able to pay him is but a very slight compensation for his labors in our behalf. And I desire again to express my sincere appreciation of his valuable services and my grateful acknowledgment for his assistance during my term as Chairman of the Board.

In closing my last report as your Chairman, I wish to thank the members of the Board for the honor which they have conferred upon me, and to assure them that I shall continue to labor for the welfare of the Association and do all in my power to further its interests.

Respectfully submitted,

S. E. TINKHAM, *Chairman.*

Annual Report of the Secretary of the Board of Managers.

PHILADELPHIA, DECEMBER 31, 1897.

Mr. S. E. Tinkham, Chairman,
60 CITY HALL, BOSTON, MASS.

DEAR SIR:—I have the honor to present the following report upon the operations of the Secretary's office during the year 1897, and of the condition of the Association at the present time.

These data are concisely stated in the following statistical appendices:

A. Statement of receipts and expenditures during 1897.

B. Estimate of assets and liabilities at the close of 1897.

C. Detailed statement of cost of JOURNAL during 1897.

D. Comparison of mailing lists of the JOURNAL, at the close of 1896 and of 1897, respectively.

E. Statement of material in JOURNAL during 1897, by pages.

F. Comparison between operations and conditions during 1896 and 1897.

From Appendix F we learn, in the first place, the gratifying fact that the excess ($2562.04) of assets over liabilities, at the close of 1897, is more than double that at the close of 1896, and this in spite of the fact that the fourth quarterly assessment for 1897 was made 25 cents per member, instead of 75 cents as heretofore, making the annual assessment $2.50, instead of $3.00, per member. It is hoped that the current year's transactions will permit the continuance of the lower figure, if not a further reduction.

The assets and liabilities, during several recent years, have compared as follows:

	Excess of Liabilities over Assets.	Excess of Assets over Liabilities.
1894	$758 91	
1895		$223 93
1896		1,244 94
1897		2,562 04

I quote, as follows, from my report for 1896:

"It is much to be hoped that the Societies will take early and efficient action in the matter of securing from their members advertisements for the JOURNAL. The present rule of the Association is to allow the Societies 50 per cent. of the cost of advertisements.

"Apart from the business advantages of the advertisement, the Societies can thus secure what amounts practically to a material reduction in their assessments, and those of their members who are in position to profit by such advertising can, in this way, aid their respective Societies at the same time that they are forwarding their own business interests."

The accession of the Detroit Engineering Society, with 97 names at the end of the year, and increases of membership in the Boston, Montana and other Societies, have brought the number of names on the mailing lists of the Societies from 1106 to 1252, showing a gain of 146 names.

The average cost per page of publishing the JOURNAL during 1897 was but $3.24, as against $4.59 in 1896. Much of the reduction is due to the use of the linotype machine for composition. In spite of a large increase in the volume of matter printed, the total cost of the year's publication was re-

duced nearly $800. The increase in the number of pages printed, from 856 to 968, and a decrease of $267.54 in the cost of illustrations, have also contributed to a reduction in the cost per page.

The number of pages published, and the average cost per page, during several recent years, have been as follows:

	No. of Pages.	Average Cost per Page.
1894	1290	$4 48
1895	1482	3 99
1896	856	4 59
1897	968	3 24

APPENDIX A.

Statement of Receipts and Expenditures During 1897.

CASH, 1897.

Dr.

To Balance, January 1, 1897		$1,119 34	
" Assessments:			
Boston Society of Civil Engineers	$1,130 75		
Civil Engineers' Club of Cleveland	433 25		
Engineers' Club of St. Louis	427 50		
Civil Engineers' Society of St. Paul	90 00		
Engineers' Club of Minneapolis	30 00		
Civil Engineers' Club of Kansas City	54 01		
Montana Society of Engineers	160 50		
Denver Society of Civil Engineers	76 50		
Association of Engineers of Virginia	161 25		
Technical Society of the Pacific Coast	566 75		
Detroit Engineering Society	227 75		
		3,358 26	
" Initiation fee, Detroit Engineering Society		41 50	
" Subscriptions		520 34	
" Sales of Journals		129 27	
" " " Descriptive Index		43 25	
" Advertisements		417 50	
" Sales of Reprints		112 00	
" " " Periodicals		29 85	
" Advance copies of paper		10 00	
" Letter-heads for Technical Society of Pacific Coast		3 00	
			$5,784 31

Cr.

By Patterson & White (Printers)	$1,935 08
" Edward Stern & Co., Incorporated (Printers)	610 46
" Illustrations	505 73
" Secretary's salary	600 00
" Car fares	3 00
" Mimeographing, etc	6 10
" Discounts on subscriptions	22 50
" " " sales	5 37
" " " advertisements	7 25

By Messenger service	3 36	
" Stationery	4 90	
" Telegrams	4 53	
" Postage stamps	36 79	
" Express charges	3 15	
" Back numbers bought	9 56	
" Amount refunded	5 00	
" To correct error of Provident Life and Trust Co.	3 00	
" Western Society of Engineers. Share of surplus at close of 1895	23 00	
		3,788 78
" Cash balance, December 31, 1897		$1,995 53

APPENDIX B.

Estimate of Assets and Liabilities at the Close of 1897.

AVAILABLE ASSETS.

Cash balance, December 31, 1897		$1,995 53	
Less subscriptions for 1898, paid during 1897		50 25	
			$1,945 28
Amounts receivable from Societies (for assessments, etc.):			
Civil Engineers' Club of Cleveland	$51 25		
Engineers' Club of Minneapolis	3 50		
Montana Society of Engineers	198 05		
Technical Society of the Pacific Coast	42 00		
Detroit Engineering Society	1 50		
		$296 30	
Subscriptions due:			
For 1897	154 00		
" 1896	60 00		
" 1895 and earlier	57 00		
		271 00	
For Reprints		125 28	
" Advertisements		208 33	
" Sales of Journals		7 00	
" " " Index		8 00	
" Copyright fee		1 00	
			916 91
			$2,862 19

LIABILITIES.

Patterson & White (Printers):			
For December Journal	$229 90		
" Reprints	12 55		
		$242 45	
Levytype Co.		22 80	
Boston Society of Civil Engineers		1 85	
Engineers' Club of St. Louis		6 25	
Denver Society of Civil Engineers		13 00	
S. E. Tinkham, expenses as Chairman		13 80	
			300 15
Excess of Assets over Liabilities			$2,562 04

APPENDIX C.

Detailed Statement of Cost of JOURNAL During 1897.

	1	2	3	4	5	6	7	8	9	10	11	12	13
	Composition.	Paper, Presswork, Binding.	Wrapping, etc.	Postage.	Patterson & White. Sum of 1, 2, 3 and 4	Illustrations.*	Cost of Manufact'e Sum of 1, 2, 6.	Wrappers.	Secy's Salary.	Sundries.†	Total.‡	No. of Pages.§	Cost per Page.
January	$132 42	$107 75	$7 83	$11 11	$248 00	$56 50	$296 67	$3 56	$50 00	$2 33	$360 39	128	$2 82
February	50 15	68 15	4 31	8 58	131 19	60 50	178 80	7 90	50 co	17 44	267 03	68	3 93
March	82 50	82 75	7 15	9 65	182 05	1 75	167 00	4 75	50 00	6 11	244 66	96	2 55
April	105 94	115 35	4 75	12 44	238 48	61 00	282 29	4 75	50 00	14 40	368 63	124	2 97
May	67 20	80 35	6 66	8 73	162 94	70 00	217 55	4 75	50 00	20 35	308 04	74	4 16
June	44 23	49 50	5 42	6 13	105 28	13 25	106 98	4 75	50 00	11 17	184 45	58	3 18
July	51 87	54 00	4 10	7 05	117 02	27 75	133 62	4 75	50 00	4 90	204 42	66	3 10
August	29 71	40 70	5 25	5 84	81 50	104 80	175 21	4 75	50 00	14 40	255 45	38	6 72
September	65 88	70 50	4 75	8 19	149 32	26 00	162 38	4 75	50 00	8 95	239 02	88	2 72
October	44 05	61 25	4 90	7 20	117 40	25 00	130 30	4 75	50 00	15 97	213 12	62	3 44
November	32 50	45 25	5 05	6 09	88 89	24 00	101 75	4 75	50 00	8 83	176 47	50	3 53
December	108 30	101 25	6 08	9 52	225 15	33 30	242 85	4 75	50 00	5 55	318 75	116	2 75
Totals and averages	$814 75	$876 80	$66 25	$100 53	$1,847 22	$503 85	$2,195 40	$58 96	$600 00	$130 40	$3,140 43	968	$3 24

*The figures in column 6 include preparation of cuts and lithographic stones, and paper and presswork on insets.

†The figures in column 10 include all expenditures of the Association (such as stationery, postage, circulars, etc.) chargeable to the JOURNAL, and not embraced in any other column. They do not include the cost of preparing reprints of papers.

‡Sums of amounts in columns 5, 6, 8, 9, and 10.

§The figures in column 13 include 4 cover pages in each number and 16 pages in indexes to Vols. XVIII and XIX.

APPENDIX D.

Comparison of the mailing lists of the JOURNAL, at the close of 1896 and of 1897, respectively:

	1896.	1897.	Increase.	Decrease.
Boston Society of Civil Engineers	431	470	39	..
Civil Engineers' Club of Cleveland	175	148	..	27
Engineers' Club of St. Louis	167	174	7	..
Civil Engineers' Society of St. Paul	35	36	1	..
Engineers' Club of Minneapolis	12	15	3	..
Montana Society of Civil Engineers	67	97	30	..
Technical Society of the Pacific Coast	149	149	..	..
Denver Society of Civil Engineers	28	26	..	2
Association of Engineers of Virginia	42	40	..	2
Detroit Engineering Society	..	97	97	..
	1106	1252	177	31
Extra copies to members of the Board of Managers, five each	80	80	..	..
Advertisers	23	19	..	4
Exchanges	108	102	..	6
Subscribers	241	233	..	8
Complimentary copies	14	14	..	..

Besides this, many copies have been sold and specimens copies sent out; and authors of papers have each received five copies of the JOURNALS containing them. Two thousand copies of each number have been printed.

APPENDIX E.

Statement of material in JOURNAL during 1897, by pages.

	Papers.	Proceedings.	Chairman's Report.	Advertisements.	Indexes to Vols.	Totals.	Cuts.	Plates and full-page cuts.
January	88	14	10	16		128	7	5
February	42	10		16		68		3
March	54	26		16		96	1	
April	98	10		16		124	11	11
May	48	10		16		74		5
June	30	4		16	8	58		1
July	44	6		16		66	25	
August	20	2		16		38	5	6
September	60	12		16		88	3	2
October	40	6		16		62		3
November	28	6		16		50	2	1
December	86	6		16	8	116	3	8
Totals	638	112	10	192	16	968	57	45
Covers						48		
Total						1016		

APPENDIX F.

Comparison between operations and conditions during 1896 and 1897:

	1896.	1897.
Excess of assets over liabilities. December 31	$1,244 94	$2,562 04
Number of Societies in Association, December 31	9	10
" " names on mailing lists of Societies in Association	1,106	1,252

	1896.	1897.
Number of subscribers	241	233
Annual receipts from subscribers, at $3.00	$723 00	$699 00
Number of advertisers	20	19
Annual receipts from advertisers	$858 00	$417 50
Total pages in JOURNAL	856	968
" " of papers	490	638
" cost of JOURNAL	$3,928 42	$3,140 43
Cost per page	$4 59	$3 24
Average number of copies issued monthly	2,042	1,796
Number of small cuts	62	57
" " plates and full-page cuts	56	45
Cost of illustrations	$771 39	$503 85

Editors reprinting articles from this journal are requested to credit both the JOURNAL and the Society before which such articles were read.

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

VOL. XX. FEBRUARY, 1898. No. 2.

THE HOLDING POWER OF NAILS IN DOUGLAS SPRUCE (Oregon Pine) AND IN REDWOOD (Sequoia Sempervirens).

BY PROFESSOR FRANK SOULE, MEMBER TECHNICAL SOCIETY OF THE PACIFIC COAST.

[Read before the Society, December 3, 1897.*]

IN each year in the United States alone from six to eight million dollars' worth of nails are used in the various branches of construction. A knowledge of the holding power of such nails as are ordinarily used in carpentry and in the arts generally, seems to be of practical value. I have desired particularly to obtain such numerical data in the cases of Douglas spruce and redwood, each of which timbers is very extensively used in building and construction on the Pacific coast. To this end we have made a set of tests in the laboratory of the Department of Civil Engineering in the University of California, at Berkeley. The numerical data thus obtained must be regarded, however, as relative and comparative rather than as absolute, and as giving working rather than theoretical results, for the reason that the number of tests has been limited by the time at our disposal, and that the results must necessarily be influenced by the kind and quality of timber used in the tests, the closeness of its fibers, its degree of seasoning, by the mode of driving and of drawing nails, the length of time these have remained in the wood, etc. Even with the same piece of timber and the same kind of nails and method of driving, it is found that only by chance are identical results obtained. The tests were made with the following purposes in mind—to ascertain:

*Manuscript received February 10, 1898.—Secretary, Ass'n of Eng. Socs.

1. The relative merits of cut and of wire nails.
2. The merits of different surfaces on the nails.
3. The best shape of nails, as to points, etc.
4. The relative holding powers of these nails in Douglas spruce and in redwood.
5. The best relation between the length of nail and the thickness of the board nailed by it.
6. The effect of time upon the holding power of nails in the cases of the kinds of timber above named.

The resistance to drawing which is offered by a nail is due to the friction against its surface offered by the long, tubular fibers composing the wood. These fibers vary in different kinds of wood, in size, hardness, stiffness, distance apart and adhesion one to another laterally. They act differently upon cut nails and upon wire nails; and upon this difference of action largely depends the variation in their holding power. A pointed wire nail, for example, when being driven forces its point between the fibers and presses

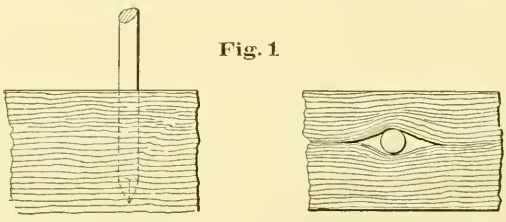


Fig. 1

them apart; and therefore the longitudinal as well as the transverse elasticity of the wood presses the fibers against the nail, unless the wood be badly split. (A simple illustration is given in the case of a wire nail being driven into the flat side of an ordinary broom.) This lateral pressure, caused by the wedging of the nail among the fibers, is the principal means of keeping this nail in place, and it is easy to see that the pressure is exerted almost entirely upon the two sides parallel to the grain of the wood. (See Fig. 1.)

In the case of a cut nail, however, as usually driven, this wedging does not take place, but the cutting edges of the nail shear off the fibers, or bend them down at a large angle as they meet them along the path in which the nail is driven. Then, if the two sides of the nail that are perpendicular to the grain are wedged, as generally they are in case of cut nails, the further down the nail is driven the more these fibers are pressed backwards; and therefore when stress is applied to withdraw the nail from the wood the more these fibers act like barbs and offer strong resistance to withdrawal. (See Fig. 2).

This supposition as to the action of the nails and fibers has been amply borne out by experiments made to test the assertion. The experiments showed that by far the greater portion of the resistance to withdrawal in the case of cut nails was due to the action of the ends of the fibers upon the adjacent surfaces of the nails, and not to the friction of the fibers against the other sides. For example, in a certain case a cut nail driven in the usual manner (Fig. 3, a) required a force of 630 pounds to withdraw it.

The same kind of nail driven between two holes, so that only the *ends* of the fibers came in contact with it (Fig. 3, b), required 300 pounds; but when driven between two holes, so that only the *sides* of the fibers pressed against the nail (Fig. 3, c), it offered only

Fig. 2

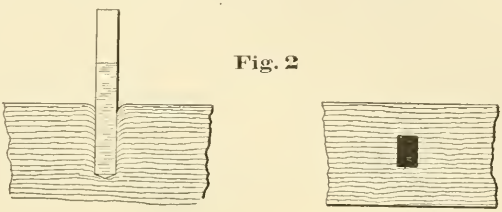
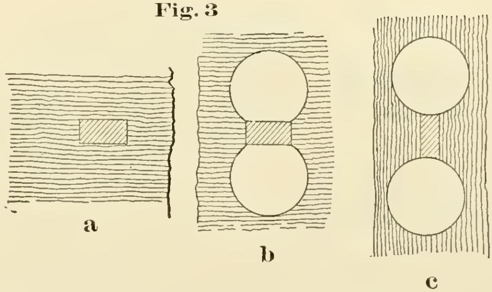


Fig. 3



50 pounds resistance. The sum of the last two resistances did not, of course, equal the first, because in that case there was a combined mutual assistance offered by the fibers which was not given in the second and third instances; but enough was shown to make it evident that the principal resistance to withdrawal comes from the ends of the fibers.

If a cut nail be driven with its wedge parallel to the fibers its holding power is increased, for the nail is held both by the ends of the fibers on two sides and by the friction of the fibers themselves upon the rough wedge faces of the other two sides of the cut nail. In other words, the nail thus driven is held both by the resistance characteristic of the cut nail and that of the wire nail.

Of course driving a cut nail with its wedge parallel to the fibers of the wood is much more likely to split the timber than

driving in the ordinary way. Hence that manner of driving is not often adopted.

The cut nail and the wire nail were compared size for size. What is known as the "cement nail" was also tested. This is an ordinary wire nail, dipped into a liquid cement which adheres to its surface. The agents claim that the heat developed in driving this nail melts the cement, which then permeates the fibers of the wood adjacent to it, and upon cooling hardens again and causes strong adhesion between the nail and the fibers, and in that way considerably increases the nail's holding strength. The cost of each kind of wire nail was the same. These nails were driven into Douglas spruce (Oregon pine) and Sequoia Sempervirens (California redwood), respectively. The nails were pulled from the timber by means of our Olsen Testing Machine.

The pulling clamps were caused to move with a small and constant velocity, the force exerted being registered upon the balance

Fig. 4.

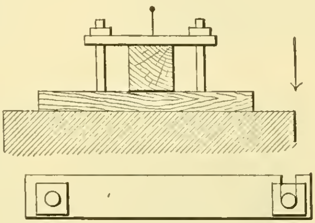


Fig. 5.

arm of the testing machine. The addition to the machine specially designed to make these tests was arranged as follows: A two-inch plank was strongly bolted to the top of the movable head of the Olsen machine. To this plank were fastened down by two screw bolts at each end, whose heads were counter-sunk in the plank, the pieces of timber into which the nails were to be driven. Each stick was held down at its ends by an iron strap above it, clamped by nuts running on the screw thread of the bolts.

The jaws gripping the nails to be drawn were made of a piece of inch strap iron, bent over into a long horseshoe form, the two ends being turned at right angles and notched to receive and hold the head of a nail. A small thumbscrew ran through the jaws and regulated the size of the opening for the nail head. This grip was fastened to the fixed head of the testing machine by means of an iron strap. (See Fig. 4). We are indebted to Mr. L. E. Hunt, instructor in civil engineering, who is in immediate charge of the laboratory, for this arrangement of the apparatus. When a nail had been driven into the timber the jaws were clamped upon it,

the machine was set in motion, the movable head, carrying the bolted timber, and the nail driven into it, was slowly pulled downward, and the jaws, fastened to the fixed head, withdrew the nail, its stress being registered at the same time on the balance arm of the testing machine. Each nail was pulled out separately in the direction opposite to its driving; and in each case at the same speed. Some cut nails were driven wedgewise, and some crosswise of the grain of the wood. Others were driven into the ends of the timber parallel with the fibers. Some nails were sharpened at their ends and others were cut off squarely.

The number of nails used in each case was large enough to furnish a reliable average result, being greater whenever there was considerable variation in the conditions of the case.

Tests were also made as to the relative merits of different kinds of nails subjected to a shearing stress.

Blocks of wood of different thicknesses were nailed together with different kinds and sizes of nails, and stress was applied to the upper block by means of the movable head of the Olsen machine, just as in the case of simple compression tests. (See Fig. 5.)

CONCLUSIONS FORMED FROM A CONSIDERATION OF THE RESULTS OF THE TESTS.

1. Cut nails for the same area hold better than wire nails.

2. The holding strength increases with the length of the nail, but not according to any simple law.

3. The pointing of the wire nail adds about one hundred per cent. to its efficiency. If slightly more pointed than they are made at present, the holding power would be increased.

4. Pointing the cut nail adds 33 per cent. to its efficiency, but it increases the tendency to split the wood. To avoid splitting, the taper side only of the cut nail might be wedged. If wedged on all four sides, it holds best.

5. Cut nails driven with wedge across the grain are only about 80 per cent. as strong as those driven with the wedge parallel to the grain. This fact does not accord with practice in driving, probably on account of the greater tendency to split the wood.

6. A nail is three times as strong when driven into the side of a beam—that is, across the grain—as it is driven into the end of it; that is, parallel to the grain.

7. The holding power of nails increases with time in case of redwood. It is asserted by some that the tannic acid rusts the nail and thus increases its holding power. It is probable that this effect would be extended over a few months only, after which the further

PULLING RESISTANCES.

Kind of Timber.	Specimen No.	Kind of Nail.	Diameter of Nail, inch.	Length of Nail, inch.	Length in the Wood, inch.	Mean Pulling Force, lbs.	Date of Driving, 1896.	Date of Drawing, 1896.	No. Days in Wood.	Unit Stress, lbs.	Area of Nail in Contact inches.	REMARKS.
Douglas Spruce.	1	Cement	.117	2.95	2.65	360	Feb. 18	Mch. 31	42			
"	"	"	.121	2.46	2.16	363	"	"				
"	2	"	.09	1.90	1.60	128	"	"	"			
"	"	3d com. wire	.075	1.30	1.00	34	"	"	"			
"	3	5d wire	.104	1.80	1.50	175	"	"	"			
"	"	8d "	.128	2.45	2 10	290	"	"	"			
"	4	Cement	.117	2.95	2.60	400	"	" 5	16			
"	"	"	"	"	"	375	"	" 31	42			
"	5	8d cut	.179 x .089 x .112	2.42	2.10	358	"	"	"			
"	"	5d "	1.78 x .163 x.082x.088	1.78	1.50	267	"	"	"			
"	6	3d "	1.35 x .107 .055 x .075	1.35	1.00	147	"	"	"			
"	"	6d "	.143 x.01 x .094 x 1.94	1.94	1.60	323	"	"	"			
"	"	4d "	1.54 x .152 .068 x .096	1.54	1.20	207	"	"	"			
"	7	12d "				541	Feb. 20	Feb. 20	0			Wedge across grain. } ....Ratio=.925
"	"	" "				585	"	"	0			" with "
"	"	8d "				368	"	"	0			" across " } ....Ratio=.78
"	"	" "				471	"	"	0			" with "
"	8	12d wire				350	"	"	0			Pointed ends.
"	"	" "				175						Points cut off. Drove much easier. } Ratio, $\frac{\text{Pointed}}{\text{Blunt}}=2.00$
"	"	8d "				182		Mch. 2				Sharp point.
"	9	" "				92	Feb. 20	Feb. 20				Cut off square......Ratio, $\frac{\text{Pointed}}{\text{Blunt}}=2.0$
"	10	20d "			3.50	650	"	Mch. 2	10			
"	"	" "			3.00	570	"	"	10			
"	"	" "			2.00	360	"	"	10			
"	"	" "			1.00	112	"	"	10			

PULLING RESISTANCES.—Continued.

Kind of Timber.	Specimen No.	Kind of Nail.	Diameter of Nail, inch.	Length of Nail, inch.	Length in the Wood, inch.	Mean Pulling Force, lbs.	Date of Driving, 1896.	Date of Drawing, 1896.	No. Days in Wood.	Unit Stress, lbs.	Area of Nail in Contact inch.	REMARKS.
Douglas Spruce.	12	Cement	.121	$2\frac{3}{5}$	2.16	365	Feb. 21	Feb. 24	3	445	.821	
"	"	"	.121	$2\frac{3}{5}$	2.16	320	"	Mch. 24	32	390	.821	
"	"	8d com. wire			2.10	311	"	Feb. 24	3	368	.844	
"	13	5d " "			1.50	206	"	"	3	420	.490	
"	"	6d " cut			1.60	374	"	"	3	602	.621	
"	16	4d " "			1.20	260	"	" 25	4	562	.463	
"	"	8d wire			1.00	67	"	"	4	284	.236	............................Ratio, $\frac{\text{Cut}}{\text{Wire}} = 2.98$
"	17	8d cut				442						Driven to ⅜ in. of head.
"	"	6d "				310						" " " " "
"	"	Wire fin. 12d			2⅝	280						
"	"	20d cut				663						
"	"	Finish n.			3½	330						
"	20	6d cut				185						Ordinary ends.
"	"	" "				395						Sharp points.
"	21	Fin. cut		2½		293						Ordinary "
"	"	" "		"		338						Sharp "
"	22	" "		"		305	Mch. 19	Mch. 24				Across grain.
"	"	" "		"		102	"	"				With "
"	"	Wire fin.		"		116	"	"				Across "
"	"	" "		"		46	"	"				With "
"	"	Cement	.09			180	"	"	5			Driven to within 0.4 in. of head.

SHEARING RESISTANCES.

Kind of Timber.	Specimen No.	Kind of Nail.	Diameter of Nail, inch.	Length of Nail, inch.	Length in the Wood, inch.	Mean Pulling Force, lbs.	Date of Driving, 1896.	Date of Drawing, 1896.	No. Days in Wood.	Unit Stress, lbs.	Area of Nail in Contact inch.	REMARKS.
Douglas Spruce.	23	20d cut	.287 x .133 x .186	4	3.90	1370				250	5.46	Heads of nails not driven quite flush with block.
"	"	20d wire	.193	4		1335				315	4.24	Two nails for each case.
Douglas S. & Redwood	24	20d cut				1200				220		" " " " "
"	"	20d wire				1300				307		

Kind of Timber.	Specimen No.	Kind of Nail.	Diameter of Nail, inch.	Length of Nail, inch.	Length in the Wood, inch.	Mean Pulling Force, lbs.	Date of Driving, 1896.	Date of Drawing, 1896.	No. Days in Wood.	Unit Stress, lbs.	Area of Nail in Contact inch.	REMARKS.
TESTS FOR DEPTH OF BLOCK IN SHEAR.												
Douglas S. & Redwood	25	8d cut n.				580						½″ Redwood blk nailed on spruce blk
"	26	" "				990						¾″ " " " " " "
"	27	" "				1200						1″ " " " " " "
"	28	" "				1100						1¼″ " " " " " "
"	29	" "				800						1½″ " " " " " "
"	30	" "				600						1¾″ " " " " " "
TESTS IN SHEAR ON DIFFERENT SIZED NAILS.												
Douglas S & Redwood	31	2 30d n.				1260				292	4.52	⅞″ Redwood blk on D'glas spruce blk
"	"	2 20d n.				1300				360	5.61	" "
"	"	3 10d n.				1190				277	4.30	" "
"	"	4 8d n.				1340				264	5.08	
PULLING RESISTANCES OF NAILS DIFFERENTLY POINTED.												
Douglas Spruce.	32	10d wire fin				183	Mch. 20	Mch. 24	4			Cut off to square end.
"	"	" " "				203	"	"	"			Beveled end.
"	"	" " "				367	"	"	"			Ordinary point.
"	"	" " "				370	"	"	"			Rounded end.
"	"	" " "				423	"	"	"			Sharper than ordinary.
"	"	" " "				543	"	"	"			Very sharp.
"	"	6d cut				360	" 24	" 31	7			Square end.
"	"	" "				363	"	"	"			Beveled end.
"	"	" "				482	"	"	"			Sharpened end.
"	"	" "				367	"	"	"			Sharpened on wedge side.
"	"	" "				422	"	"	"			" " other "
"	"	" "				437	"	"	"			Very sharp

PULLING RESISTANCES.

Kind of Timber.	Specimen No.	Kind of Nail.	Diameter of Nail, inch.	Length of Nail, inch.	Length in the Wood, inch.	Mean Pulling Force, lbs.	Date of Driving, 1896.	Date of Drawing, 1896	No. Days in Wood.	Unit Stress, lbs.	Area of Nail in Contact inch.	REMARKS.
Redwood	33	Cement		2.95	2.50	357	Feb. 21	Feb. 25	4			
"	"	"		2.95	2.50	333	"	Mch. 31	40			
"	34	10d wire	.143	3.10	2.50	387	"	"	"			
"	"	10d cut fin.	3 x .08 x .283 x .116	3.00	2.50	477	"	"	"			
"	35	8d cut				293						Driven to 3/8″ from head.
"	"	6d "				235						
"	"	12d wire fin.			2.5/8	292						
"	"	20d cut				528		"				
"	"	Finish n.		3.50		362						
"	36	Fin wire			2.50	270						Tests for depth driven.
"	"	" "			2.00	220						
"	"	" "			1.50	179						
"	"	" "			1.00	100						
"	"	" "			.50	30						
"	37	8d cut				475	Mch. 9	Mch. 31	22			
"	"	" "				325	"	"	"			Rough and poor nails
"	38	Cement	.121			245	"	" 10	1			
"	"	"	"			269	"	" 31	22			
"	39	Fin. cut		2.50		327	" 12	" 17	5			Across the grain. ……Ratio=2.7
"	"	" "		"		121	"	" 17	5			With the grain.
"	"	8d cut				382						Across the grain. ……Ratio=3.38
"	"	" "				113						With the grain.
"	"	Wire n.	.129	2.50	2.3/16	460						Across the grain. ……Ratio=3.28
"	"	" "	"	"	"	140						With the grain.
"	40	20d cut			3.50	960	Mch. 19	Mch. 24	5			
"	"	" "			3.00	755	"	"	"			
"	"	" "			2.50	500	"	"	"			
"	"	" "			2.00	360	"	"	"			
"	"	" "			1.50	265	"	"	"			
"	"	" "			1.00	90	"	"	"			

SHEARING RESISTANCES IN REDWOOD.

Kind of Timber.	Speci-men No.	Kind of Nail.	Diameter of Nail, inch.	Length of Nail, inch.	Length in the Wood inch.	Mean Pulling Force, lbs.	Date of Driving, 1896.	Date of Drawing, 1896.	No. Days in Wood.	Unit Stress, lbs.	Area of Nail in Contact inch.	REMARKS.
Redwood	41	2 20d cut.	.287 x .133 x .186 x 4	3.50	4.00	1355				248	5 46	Two nails in each.
"	"	2 20d wire.	.193		4.00	1320				311	4.24	Two nails in each.
Douglas S. & Redwood	42	2 20d cut.				1200				220	5 46	Redwood blk on Douglas spruce blk.
		" wire.				1300				307	4.24	" " " " " "
"	43	2 30d				1260				292	4.52	Fastened ⅞ in. Redwood cleats to Douglas Spruce block.
"	"	2 20d										Tests for different sizes of nails.
Redwood	44	10d wire.				367	Mch. 30	Mch. 31	1			Time test of nails in Redwood.
"	"	10d cut fin.				392	"	"	1			

rusting of the nail would weaken it. The effect of time in case of cement nails does not seem to be great, and is only slightly greater in case of wire nails, but is very considerable for cut nails.

8. The tests show that all these nails lose holding power with time when driven into Douglas spruce. This probably may be accounted for by the small lateral adhesion of the fibers in this wood and their gradual yielding to the wedge action of the nail. In other words, they pinch the nail less and less with time, but it seems unlikely that this diminution would continue indefinitely.

9. In redwood a cut nail holds slightly better than a wire nail.

10. In Douglas spruce the cement nails are 1.3 times stronger than the wire nails.

11. A cement nail is slightly stronger than a wire nail when driven into redwood, but the difference in strength is small.

12. Under shearing stress cut nails are 1.4 times stronger than wire nails. There seems to be no difference in the resistance of the nails to shear in using blocks of Douglas spruce or of redwood.

13. When nailing cleats to a block the same area of nail in the wood will hold about the same stress, whether a few large nails are used, or more small ones. The superiority, if any, is in favor of the larger nail.

14. The cut nail holds 1.33 better in Douglas spruce than in redwood; the wire nail about the same in each, with a slight superiority in favor of redwood.

15. The holding power of a nail is not directly proportional to its surface in contact with the wood. In determining the relative holding powers, the stress per unit area has been employed, but as far as possible nails have been taken as nearly alike as practicable, so as to eliminate the error introduced by this method.

16. In drawing a nail, the pull seems to reach a maximum shortly after the nail starts.

17. In case of a wire nail, the applied stress increases gradually; of a cut nail by jerks and starts. The decrease of holding in wire nails after reaching the maximum is gradual, while in cut nails it falls off suddenly. Hence, a cut nail is not as efficient in holding together pieces of timber subject to vibration as is the wire nail, for the former is more easily loosened, and, being partly withdrawn, loses much of its strength. This results from the fact that the major portion of the resistance comes from the wedge sides of the nail.

18. Cut nails are more likely to split Douglas spruce, and wire nails to split redwood.

19. In shearing a cleat from a block to which it is nailed, a

maximum resistance is obtained for a cleat the thickness of which is $\frac{2}{5}$ of the length of the nail used. This agrees closely with the practice of using a nail about $2\frac{1}{2}$ times the thickness of the thinner piece nailed.

20. A slight roughness on the surfaces of a nail is of advantage.

21. The cut nail is more efficient when driven into Douglas spruce, but the wire nail is more so in redwood. This fact bears out the theory as to the manner in which a wire nail holds. The lateral pressure of the redwood fibers is greater than that of the fibers of Douglas spruce, on account of the closeness of the grain of the redwood, it having 39 annular rings to the inch, as against 14 for the spruce; and this holds true, notwithstanding that the redwood is softer than the spruce.

The general conclusion from our tests is that for most uses and under most conditions the cut nail is superior to the wire nail.

DISCUSSION.

President Molera.—Gentlemen, you have heard the excellent paper by Professor Soulé. Such papers, based on original research, are the kind we need to have presented before this Society. We have architects and others present who have had a great deal of experience in the use of nails of all kinds, and we shall expect to hear from them.

Wire nails have been in use in Europe for a number of years, but as far as I have observed they have not been used extensively in this country until within the last four or five years. So now it is quite an important question as to the relative strength and holding power of wire nails and cut nails. I have heard a great many carpenters talk upon this subject, some advocating the use of wire nails, while others are equally confident that cut nails are the best. These scientific tests will prove very useful. I hope all those present who have any facts bearing upon this subject will bring them forward, and that we shall have a thorough discussion of this question.

Mr. Percy. It is pleasant to have what we think we have learned by practice and observation confirmed by scientific research. I must confess that when the use of the wire nail was first introduced I took quite a fancy to it, being converted to the idea that it was a better nail because the section of the wood where it was driven through was less bruised as compared with a cut nail. Take soft pine, for instance, and cut open the section where a cut nail is driven in and expose the fiber, and it is very much torn and

bruised, while in the case of a wire nail the fiber is very little mutilated.

Three or four years ago I commenced to provide, in my specifications, that wire nails should be used. I found that mecharics generally favored them, or readily took to the idea. Everyth'ng went along harmoniously, but occasionally I would meet with a practical mechanic who argued that the wire nail was not as good as the cut nail. Although perfectly willing to use it, he did not believe it was as good. This led me to watch results very carefully, and I soon became convinced that the cut nail was better for exposed places. I found, especially in places where boards were disposed to warp and twist, owing to the condition of the weather, that wire nails would draw very much more readily than cut nails. In such climates as the San Joaquin Valley and up in Nevada I found that wire nails would not answer the purpose at all; that rustic nailed on to the side of a house would draw the nails out. So, in such places as that, I went back to the use of cut nails, and deliberately stipulated that wire nails should not be used. In places where the weather is not a factor I think wire nails will last as long as cut nails.

I was interested to learn that in redwood wire nails were quite as good, if not better, than cut nails. I had never had my attention called to the fact before this evening.

In Fig. 3, c there is represented a cut nail driven with the wedge paralell to the fibers. It seems to me that is an unfair test, as the holes are larger than the section, and therefore cut the fibers off on each side of the nail, so that they have not a fair chance to display their strength. Compare that with the case shown in Fig. 1, where the round nail pushes the fibers apart. Here the fibers are holding like bowstrings on the nail. Fig. 3, c shows only 50 pounds resistance. The bowstring pressure is entirely absent. In Fig. 3, b where the holes are the size of the nail, they have less effect, and the fibers which they cut off are not those which act on the nail.

President Molera.—Did you make tests of nails driven diagonally to the fibers?

Professor Soule.—No, we did not.

President Molera.—As wire nails are circular in form and can the more readily be driven in any direction as compared with cut nails, I think it would be of some interest to make tests of nails driven diagonally through the fibers.

Mr. Henny.—Was the head of the nail left projecting so that it could be readily taken hold of by the machine?

A.—It projected just enough for the clamp to take hold of it.

Q.—About how much?

A.—About three-eighths of an inch in each case. An account was taken of the length and the surface of the nail in the wood.

Q.—The probability is, then, that a cut nail, when driven fully in, would hold more than the amount shown in the experiments?

A.—Yes.

Q.—As to the shear, in the experiments Oregon fir and redwood show the same resistance. Did the nails themselves shear off between the faces of the samples tested, or did the wood give way before the nail?

A.—The nails were little distorted, but not much, and then they broke off between the two blocks. The nails cut into the wood a little before they broke, but it was a shearing of the nail and not any material cutting of the wood itself.

Q.—It seems that the harder wood shows about the same in that respect as the softer wood. That certainly is a very interesting fact.

A.—I do not remember positively, but I think that the nails cut but very little more into the softer wood than into the hard wood before the rupture occurred. I am not certain about that. The nails cut into each block to a certain extent, so that the blocks were a little loose, one on the other. At the time of the rupture the nails did probably cut more into the soft than into the hard wood. But, as far as the holding of the nails was concerned, it did not seem to make any difference whether two pieces of Douglas spruce were nailed together, or one block of redwood and one of some other kind of wood were fastened together. Of course we were not measuring the amount cut into the wood, but the amount the nails would hold.

Mr. Grunsky.—Were any experiments made of the holding power when a nail was driven radially through the wood, or tangentially to the rings?

A.—No tests of that kind were made. The nails were driven in parallel to the grain..

Mr. Storey.—I understand the experiments were made with commercial nails, taken as they come, using nails of equal length but not of equal superficial area?

A.—As far as possible we would drive a cut nail and a wire nail to the same depth, and select them of the same size, so that the cross-section of the cut nail and the wire nail would give about the same area. We tried to equalize them by having about the same amount of metal in each nail.

Q.—Then you had special nails?

A.—Special sizes. We equalized them as far as we could, and then we compared lengths and compared surfaces. As I say in my paper, the resistance to the drawing was not strictly proportional to the length or to the surface.

MODERN GAS ENGINEERING.

By M. S. Greenough.

[An address delivered before the Civil Engineers' Club of Cleveland, January 12, 1898.*]

In order to make clear the various improvements which have characterized the manufacture of gas during the present generation, I shall have to go a little into detail in describing to you the methods by which gas is ordinarily manufactured in a first-class modern gas plant. There have been no great revolutions in gas making, so far as making gas from bituminous coal is concerned. The same principles that are now used were discovered when gas was first brought to the notice of the public, about one hundred years ago. I think it was in 1798 when Murdock first lighted his shops in Birmingham. It was, I think, in 1802 when Pall Mall was first lighted with gas. In 1807 the first great gas company of London applied for its charter, which was refused; and in 1812 it obtained the charter under which it is working to-day.

At that time it was known that if bituminous coal be placed in an iron vessel and heat applied externally, the product was a combination of gas and coal tar, which it was necessary first to cool, then to wash, then to purify and then to measure, substantially on the same principle as is done in ordinary coal gas works to-day. The methods and principles are the same, but the details of the apparatus are entirely changed.

I will now show you the plans of the principal parts of a modern gas works, and indicate how they have been modified in their workings during the past few years. (Exhibition of blue prints.)

The Willson Avenue Gas Works in this city is a very good example of modern coal gas works. The coal is brought in at the side, being put into sheds, and then taken by a hydraulic system on hydraulic elevators and deposited on the floor, where it is put into retorts and made into gas. Thence the gas passes to an exhauster, then to a condenser, a purifier and a meter; then to the gas holder and to the governor house, from which it is sent out to the different parts of the city. The method is substantially that adopted in all modern works. It is only of comparatively recent date that it has been thought advisable to take the gas, with pumps, direct from the retorts. Formerly it was washed and condensed before pass-

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ing to the exhauster, but that practice has been generally abandoned.

The old theory was that the money was made in the retort house, and to a large extent that is so, because nine-tenths of the money is expended in the retort house. It is in the small details of saving a cent here and a cent there that the company realizes its profits.

The principal advance in gas making during the last twenty years has been in the adaptation of the Siemens furnace to heating retorts. Years ago Mr. Siemens himself used his furnace in heating the retorts of the Paris Gas Company, but it required so much care to shift the valves back and forth that its use never grew to any considerable extent; and it lay dormant until the Germans, that scientific people, took up the question. After an immense amount of experiment in Germany and in this country, there have been evolved a considerable number of full depth regenerative furnaces.

In our works we use the Klöune Regenerative System. The furnace is filled with coke raked in from the retorts. The coal is raked into the furnace substantially two-thirds full, and the producer gas, made of carbonic oxide and nitrogen, with a little hydrogen passing out through the nostrils, is burnt in the combustion chamber, where it is joined by the secondary air supply, which, coming in at the side, passes up through the flues and arrives in the combustion chamber at a very high temperature. The primary air supply also is heated before it comes in under the grate bars. The temperature in the combustion chamber is so high that no sufficiently refractory material is to be had in this country that will stand it, and we have to import a material from Stettin. By this system about one-fourth of the coke is saved, and this amounts to a very considerable sum of money in the course of a year. Three to four bushels saved, to a ton of coal carbonized, make the investment advisable. The amount of coal carbonized in these retorts, on account of the extreme heat, is much greater, and so the cost of labor is decreased. And, as the retorts themselves are exposed to more equable heat than in the ordinary setting, the material lasts longer than in the ordinary retorts at a lower temperature.

The introduction of regenerative gas firing into modern coal gas works has revolutionized the detail of the system of the retort house. I will follow the gas as it leaves the retort for a moment, and then come back to the question of handling material.

The gas itself, coming out of the retort, where it has been exposed, during the latter part of the charge, to a temperature of

probably 2200 ° F., goes into the the first piece of apparatus at the temperature of not much over 130°, practically all of the heat having been absorbed in gasifying the material out of which the gas is made. The gas in the retort itself is a most delicate article. It is in that part of the work that the utmost care has to be observed. Originally retorts, made of iron, were tight, and, for a short time, gave admirable results. But after a number of years it was found that retorts made from clay would stand a higher heat and stand it longer. These retorts, however, were porous, and it was impossible to get the gas out of them, when subjected to the pressure of the rest of the apparatus, without its going through the pores; and the exhauster therefore had to be invented. This is a rotary pump which relieves the retorts from pressure as carefully as possible. The gas in the retort is on balance. If there is a pressure on the retort the gas is pushed through the pores of the retort, but if you have a vacuum on the retort air is pulled through the pores and spoils the gas. Regulating the pressure on the retort requires the utmost care. When the retort is opened for charging a very simple device prevents the gas from going back into the retort. On top of the bench stands a hydraulic main filled with water. The pipe bringing the gas up from the retort comes over and plunges down into the water. The gas comes off from the retort and bubbles up through the water, and is taken away. But as soon as the lid is taken off the retort the water makes a perfect seal. In the hydraulic main there must be a vacuum, which will counteract the seal and keep the pressure as even as possible, so that there shall be no more pressure than can be avoided, and at the same time no risk of drawing anything through. An automatic device records the vacuum running to the exhauster. Also, during every hour of the day, every length of the main at our works is tested as to pressure, and this report is brought into the office, showing that there has been neither an excess nor a deficiency of pressure. It is just by care in very small matters like this that the gas company succeeds in getting out of its coal all there is in it. After the gas has been taken away from the retorts it is easy to cool it. There are many ways, all equally efficient. The gas can be cooled by passing it through a number of pipes, or passing it through a hydraulic condenser, which will absorb heat more readily, but which has its disadvantages. In either of these methods much of the coal tar which has been produced is shaken out. Then the gas is passed through washers where the ammonia is taken up. In that process much of the other impurities comes out, but the gas is still full of sulphuretted hydrogen and bisulphide

of carbon. English coal is very full of sulphur, and, if it were not treated for bisulphide, it is possible that some inconveniences might arise from it. In some great works in Europe the gas goes through three processes, and the active chemist is continually occupied to see that the purifiers work properly. First it goes through a check purifier of lime, which is kept going until a little carbonic acid is found at the outlet of the purifier. It then passes through a set of purifiers filled with foul lime until bisulphide of carbon appears at the other end. It then passes through oxide of iron and parts with the sulphide of hydrogen. No gas company in this country passes its gas through more than one set of purifiers. Our coal is less impure than the English coal, and our gas manufacturers are less hampered by restrictions than are gas manufacturers in England.

Purifiers require considerable study. Some of our modern chemists claim that no living man actually knows what goes on inside of these purifiers, but after a manager finds his purifiers working right he generally pays no further attention to them. He sympathizes with the old-fashioned gas manufacturer who said that he didn't give a d—n about his oxygen or his hydrogen; give him the coal, and he would cook the gas out of it. Most of us feel so with regard to the purifier. As long as we get the sulphur out of the coal, just what takes place inside of the purifier is a matter of profound indifference. When, as a young man, I went into the gas business there was hardly a bushel of oxide of iron used in this country. At present scarcely anything but oxide of iron is used. It is made from cast-iron borings, mixed with sawdust, and as much of it as possible is placed in the purifier. Instead of putting in thin layers, as formerly, the depth of oxide is now limited only by the size of the purifier. I am just preparing to enlarge my purifiers 50 per cent., and I propose to fill them up six feet deep. The difficulty of handling the oxide afterward is to be considered. If it has to be taken out every time and revivified, as used to be the custom, the expense for labor is great. But if it can be revivified as it stands in the box the case is entirely different. Some nine years ago and ingenious young fellow in Massachusetts discovered that there was no necessity for putting oxide out of the boxes; that a vacuum on the bottom of the box would suck air down through it and revivify it just where it was. It is true that attempting this would probably set the oxide on fire two or three times, and might cause considerable embarrassment. Still, after experiencing a conflagration or two one learns how to handle them. The result

is that the cost of gas purification has been cut in two. The material is no longer taken out of the box unless it is caked.

Ordinarily, gas is purified by the center seal system; that is, by a large iron circular box in the center of the house, which, when the top was moved, changed the passage of the gas from one purifier to another. There are always three boxes in operation, and one of these is always off. The amount of gas which can be purified in one of these boxes was pretty carefully calculated, because it ought not to go through beyond a certain rapidity; and the slower it went the better it combined with the oxide. Two or three years ago that system was generally used, but by running a pipe along the wall and using two boxes together, instead of three, with the same purifiers, we increase the capacity, as the gas travels with half the rapidity and the work is really all done by one box in either case. In this arrangement, which I think of putting in this summer, we propose to put into the center of the house an elevator which shall take the purifying material from the cellar, when it shall have been dumped there from the boxes, and lift it up to a revolving distributer from which any box can be filled without handling. The covers also are lifted by a traveling crane on an overhead system of rails, and the whole thing is actuated by an engine. With a system of rapid rope transmission it will, I think, make a rather novel purifying house, and more complete than any I have recently seen.

After the gas leaves the purifier there is nothing to do but measure the gas and put it into the holder. The large gas holder which we have put up at the foot of Willson avenue holds nearly 1,800,000 feet. It is made with three sections, shutting up like a telescope. There is nothing in which real engineering has done more for gas manufacture than in the direction of gas holders. Until a short time ago there were few gas companies in this country with holders that held more than 450,000 feet. Now they are making them to hold from 3,500,000 to 4,000,000, and putting them up four lifts high, outside of their steel or masonry tanks. A few years ago it occurred to Mr. Livesey, of the South Metropolitan Gas Company of London, that there was no necessity for carrying the columns so high. Mr. Livesey has probably done more for gas engineering than any other man of his time. The ordinary method of constructing gas holders is to put up steel columns, against which the guide wheels rest, and which hold the gas holder steady against the wind to the full height of the holder. The strength of these columns or girders has been continuously increased by the use of the best engineering methods. It occurred

to Mr. Livesey, however, that if the vertical bars were sufficiently strong, and the top and bottom curbs which go around a section were sufficiently stiff, that section could not get out of place. He constructed an enormous gas holder with two lifts rising out entirely above these columns, and sticking up in the air without any support, except the stiffness of the curbs and of the vertical bars. I cannot say personally that I am quite in favor of that system. I think the risk is greater than the few thousand dollars saved, and the satisfaction of saving them would not equal the annoyance one would feel if the structure fell. But I think it is as clever a piece of engineering work as anything that has been put into the gas business.

When a gas engineer undertakes to save money, in running a large gas works, he should do it in saving the retort house labor; and for that purpose there have been many inventions in the course of the last twenty years in this country and abroad. I will show you, first, the system which, after considerable deliberation, we adopted to some extent in our own works, and which is operated by hydraulic power. Some machines, one of which we have in our other works, are run on rails by steam, and carry their own boilers with them as part of the machine. There are machines which are run by compressed air, and do very well indeed. One run by water was the invention of the corporation gas manager in Glasgow. It has met with considerable approval and success. We concluded to erect a hydraulic plant, and distribute the water through the retort house in various places where the machines can be fastened to it. We have so far introduced machines only for drawing the coal from the retort. It requires considerably more overhead machinery to charge the coal. I also wished to test thoroughly the simpler machines.

In Europe the coal is dumped from the track to a boot, and is then lifted by an inclined elevator to the top of the retort house and dumped into bins. Thence the coal runs into the hopper on a traveling machine, and that machine, being brought opposite the mouth-piece of the retort pushes the coal in. The coal runs into the mouth-piece of the retort, and a hammer shoves it in by several strokes, decreasing in extent as the retort is gradually filled. After the coal has been through its proper course of distillation, it is raked out by the leisurely working machines; and, as the water has served its purpose of pressure, it runs out at one end of the cylinder upon the hot coke, partially extinguishing it as it falls through into the cellar. The use of this machine has decreased the cost of manufacture, and has, to a certain extent, lessened the risk of labor

strikes. In order to carry that still further, I have under consideration a plan which I have not yet put in operation, though part of it I propose to try this year. It is proposed to take the coke, as it drops into the cellar, and carry it out on an endless collection of overlapping trays passing around wheels, then empty it into a second inclined series of trays and carry it into a coke bin which stands over the railroad track. On the top of this bin would be an agitator, which, instead of breaking the coke, would shake it and deposit it automatically in bins for different sizes which would be standing above the track; and what coke could not be stored in these bins would be dropped by tripping one of these carriers. Afterward it could be taken by a scraper and carried through an elevator, brought overhead and screened, and put into the bins as desired. That system is in use in one city in this country, and is working fairly well. It is a labor-saving device, and has something of a future before it.

Some say, "What is the use of this system? Let us build our retorts on the slant and save the labor of drawing and charging." That was the invention of a Frenchman, who thought that if he put his retorts on a proper slant he could run his coal in from the top and it would spread itself evenly through the length of the retort; and that when he wanted to take out the coke he could open the lower door and stir it with a poker and it would come out itself. The scheme has worked pretty well, and there is a very considerable feeling at the present time in England and France, and it is spreading in this country, that, after all, that may be the way to build a retort. In England, instead of setting the retorts back to back, as mine are, the stack is split in two in the middle, and there are two sections. The coal is brought in overhead. Then it is run from a bin into a small wagon holding a specified amount, and that wagon is brought over the mouth-piece which fits over the upper end of the retort. The retorts are built on just the proper slant. That does away with nearly all the labor, as it works by gravity. Many look upon this as a very marked step forward in the manufacture of gas, but, as contrasted with the gas work which does its drawing and charging of retorts by machinery, the actual saving in money does not amount, I am told, to more than half a cent to a thousand feet of gas; and it is impossible, as yet, to say whether the loss in some other respect does not more than balance the saving of labor. If a man can run an inclined retort one might ask, "Why not use a vertical one?" The same suggestion has occurred to many, and much money has been spent in trying to make a vertical retort work. But the difficulty

is in getting the gas off through the coal without breaking up the illuminating and oily vapors.

There is a great deal of money now going into coke ovens, and a large establishment is now being erected in Boston with the intention of selling a certain portion of the gas to the gas companies for illuminating purposes. At present none of it is being used for illuminating purposes except in a small town in Germany, and that gas is of very low grade. But these gentlemen claim that the gas out of the first part of a charge can be used for illuminating purposes, and that from the second part of the charge for fuel purposes. The gas industry is waiting with some interest to see whether the process is successful.

This is substantially all that is to be said on the subject of coal gas. But if we look only at the improvements in the manufacture of coal gas, and overlook the invention of water gas, we miss what is being used by fully one-half of the people in this country. It has been interesting to watch the development of the water gas manufacture. It came altogether from the introduction of cheap oils, and the attempt on the part of the oil people to find some market for their product. The first place in this country in which any effort was made to distribute gas made from oil was Saratoga, and the second Detroit. Twenty years ago I went to Detroit and found, with that pleasure which a man often finds in the failure of a thing in which he is not interested, that this process was not a success; that the oil was not being gasified, and that people seemed to think that the oil gas question was knocked in the head, especially as we heard that oil wells were giving out, and there was going to be no large yield of petroleum.

But at last a man modified the process in such a way as to make a merchantable gas. It was not a brilliant success at first, but it worked sufficiently well to make a great many gas companies unhappy all over this country; because as soon as men had a process by which they could claim to make a better gas than the other gas companies could make, they promptly applied to the city councils for charters; and said they had the patents, and told h w the city was being robbed and "skinned," a statement which at once met with the most enthusiastic reception on the part of the citizens. In most of the large cities in this country charters w re granted to new companies, but this was bitterly regretted afterward, because the competition between the old and the new companies was such that they soon had to come to some kind of terms, and the result was that the companies combined with a double capital; and the last state of that city was worse than the first.

There seems to be a theory on the part of the public that gas companies will fight vigorously for its benefit, but there is not a single competing illuminating gas company in this country. As water gas was being used at the time as a weapon in the hands of the gentlemen who wished to get part of the business, it was looked upon with considerable disfavor. They doubtless succeeded in making a gas of brighter quality than coal gas, and one which makes the company using it substantially free from labor strikes, because the amount of labor used is small, its manufacture being almost wholly a question of machinery; and I have never known of a labor strike in a water gas plant.

The objection which was raised to water gas, and raised very bitterly by the gas companies throughout the country at one time, was the danger which follows its use, in that the large per cent. of carbonic oxide which it contains was distinctly a menace to public health; and the older and more conservative gas companies labored under the impression that anything dangerous to public health ought to be abated. While their facts were all right, their conclusions were erroneous, because, so far as I can see, the public does not much object to being poisoned by gas or run over by electric cars, or shocked by electric wires, provided the man who does not get run over and does not get shocked or smothered has his gas or electricity a little cheaper. It was perhaps an error of judgment on the part of the old gas companies that they allowed themselves to have any scruples against the introduction of this thing. Now that the matter is being brought up in England, where they have begun to use this gas, there have been some accidents; and the English public does not seem to feel inclined to look at the matter just as the American public does. Those who are introducing water gas there say that the American public does not mind the risk, and that there is no reason to think it is more dangerous than coal gas. But the English authorities have interfered. It is very difficult, from a leak of coal gas, to keep enough in the room to give a dangerous percentage; whereas one per cent. carbonic oxide, breathed for an hour or two, is fatal. Gas escapes so quickly from an ordinary room that unless there is a large percentage there is little danger, and it is almost impossible to get the dangerous percentage from coal gas, unless by putting a pipe down one's throat and smothering one's self. But if the gases are mixed in the proportion of only half and half, the English authorities think they will allow the use of water gas. It is so easy to make, and insures one so well against strikes, that its use has been continually spreading; and I admit, although I was for many years

strongly opposed to it, I have been so disturbed myself by labor strikes and coal strikes in this country, and by the risks which come to the coal gas company of finding itself without the means of supplying the city, that I have prepared a series of plans for the erection of a water gas plant of sufficient size to enable me to face a prolonged coal strike. I did it with considerable hesitation, but I think it is not an unwise step to take.

In the manufacture of water gas a cupola, such as this, is filled with any solid fuel. Soft coal does not answer well. The hard coal or coke is put into the cupola, which is about 12 feet high, and a blast is put under the material after it has been kindled till the whole mass is brought to a high state of incandescence. This practically turns the generator into a producer, and the gas from that producer passes over into a super-heater which is filled with brick, and from that it passes again into a second super-heater, which is also filled with brick all the way to the top; and there are openings in both of them to introduce a secondary air supply. The blast, or the producer gas which comes over, finishes its combustion here, and brings all that brick to a bright red heat, the final products of combustion passing out of the top and going through the chimney. Then the cover is shut, and a jet of steam is put on underneath the cupola, and, passing through the incandescent mass of coal or coke, it promptly becomes carbonic acid and hydrogen. The carbonic acid, as it goes through that mass, becomes carbonic oxide to a very large extent. There is generally only 5 or 6 per cent. of carbonic acid left in. As it comes out through into the super-heaters it is met by a spray of either crude oil or naphtha, and passes down through the first and up through the second until the whole material is fixed into permanent gas. Then it goes off to the purifier, which is treated exactly as in the manufacture of ordinary coal gas. Very nearly one-half of the gas made in this country is now made by one water gas process or another. You can take your choice, but they all substantially come back to the disintegration of steam by red-hot carbon, and enriching it in some way with the products of petroleum.

At the time of our contract there was much talk about the pressure at which gas should be distributed. One of the provisions in the ordinance originally was that the pressure should be between 13 and 15 lines; that is, between 1.3 and 1.5 inches. I asked, "Does this mean that the pressure shall not exceed these limits in any part of the city at any hour of the day or night? If so, we cannot comply. We will do the best we can, and our operations shall always be under the control of the

Director of Public Works, who can control the pressure." The matter was finally left in that shape. The aim of this company has been to give the consumer, at his meter, a pressure of something over an inch, to lay large mains in the streets and large service pipes, and to keep the pressure as low as possible consistent with giving a good, strong, steady flame. The flame should stand out. In order to secure this, and to give the best service, I had prepared for my own use a map of the city, showing the large lines of feed pipes which exist throughout, and which have been added to from time to time. In order to regulate the pressure, we have several pressure gauges. We keep one at the office, one at the residence of Mr. Hyde, on Kennard street, and one at Fairmount street, besides those at the works. The pressure on the mains is regulated by very accurately adjusted governors, and the taking off or putting on of a weight changes the pressure on the whole line of the main. As evening approaches the pressure is increased, and as the consumption falls off the pressure is decreased.

Fig. 1 is a facsimile of a pressure sheet as it came into my office January 8, 1898. The solid lines indicate actual gas pressures, and the broken lines the pressure at the works required to maintain them. My office is about fifty feet, in elevation, above the governor. The gas rises in pressure ordinarily one-tenth inch for every ten feet, so that the pressure at my office is bound to be half of an inch greater than when it leaves the governor. If it were 1.5 inches at my office, it would be one inch at the works if there was no consumption. As the afternoon goes on the pressure is increased till it rises from 1.2 inches up to about 1.5 inches, and then gradually falls off again. During the night it is reduced as low as we can get it and still have enough pressure on the street lamps. The business in the resident end of the town is substantially done by the 30-inch pipe. The 24-inch pipe on Willson avenue is used comparatively little. To keep the lines even on this sheet requires an adjustment every five minutes for an hour, and then a readjustment for three hours before it gets down. These sheets show the success which has attended the effort to keep the service pressure constant, and the care which is necessary to do this. The broken line shows the action of the governor, and the solid line the result of it. It is only fair to the Cleveland Gas Company to say that I know of no company in this country that distributes its gas under so low a pressure as we are doing here, with such regularity.

Fig. 2 shows the great difference of consumption at different times in the day. The upper profile shows the total consumption

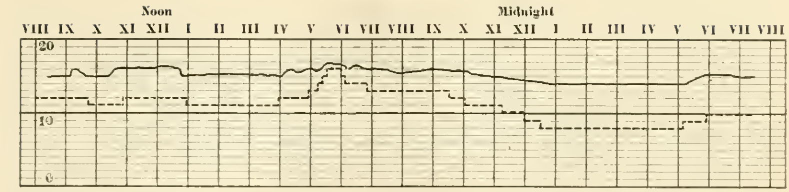

FIG. 1. PRESSURE AT WORKS NO. 1, AND IN MAIN 1 MILE EAST. (BUSINESS DISTRICT.)

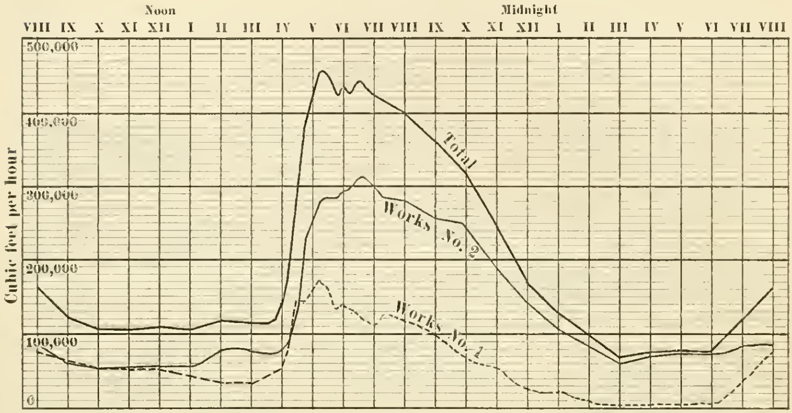

FIG. 2. QUANTITY PROFILES.

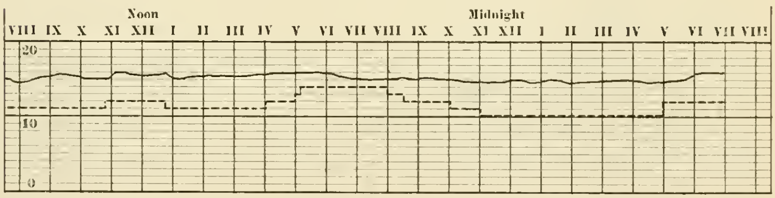

FIG. 3. PRESSURE AT WORKS NO. 2, AND IN MAIN 2 MILES SOUTH. (RESIDENCE DISTRICT.)

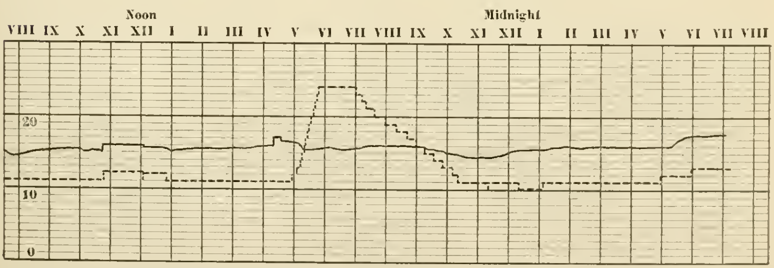

FIG. 4. PRESSURE AT WORKS NO. 2, AND IN MAIN 2½ MILES EAST. (RESIDENCE DISTRICT.)

per hour during the twenty-four hours. This profile was taken on the day before Christmas, and all through the morning, from 9 o'clock to 3 o'clock in the afternoon, the city burned at the rate of 110,000 feet of gas an hour. Between 4 and 5 P.M. the consumption increased enormously, and between 5 and 6 P.M. 460,000 feet of gas per hour were being burned. At 7 o'clock, as people began to go home from downtown, the consumption gradually fell off. The lower profile shows approximately the downtown consumption. The total output was four and a half million feet of gas for the twenty-four hours ending 7 A.M. December 25.

The business has grown steadily, increasing constantly as the price has decreased.

If any one had said fifteen years ago that he could make gas for the price at which it is sold here to-day, he would have been looked upon as crazy. In the history of this city there has never been so much gas-pipe laid as during the past year, and I think there is a sufficient future for the gas industry, and that we need not fear being snuffed out by electricity or acetylene.

DISCUSSION.

Mr. W. R. Warner.—Will Mr. Greenough kindly tell us something about gas meters? I think it would be interesting for the gentlemen here to know what proportion of the meters used by the gas company read too high, and what proportion read too low.

Mr. Greenough.—I always hesitate to speak on the subject of meters, because everybody has a friend who has a meter that does not register half as much as his does, although he burns twice as much gas. Five years ago we instituted a series of systematic tests of all the meters in the city, and this year we completed our test. No meter comes into the company's office but what is retested before it is allowed to go out, and a record is made of that test. The result is that some meters have been tested more than once, because every time a consumer changes his residence he gives up his meter, and it is brought back into the office and reset when a new consumer moves in. So that when we have tested all our meters, now numbering more than 20,000, the number tested was more than 25,000. The figures for last year are now being made up. I have not seen them, but I think that, for the year before, about 70 per cent. of the meters were correct. When we say correct, we mean within two per cent. of exactness, one way or the other, which is the Massachusetts standard. About 15 per cent. of these meters registered against the company—they

were slow; about 7 per cent. registered against the consumers—they were fast, and the balance were out of order and had to be taken to pieces. These figures are at the service of any one who would like to see them.

Mr. E. P. Roberts.—About what is the limit of those reading too high and too low which are included in that 15 per cent., for instance?

Mr. Greenough.—I could not say that there was any limit which was never surpassed, but meters very rarely exceed 10 per cent. of error. A dry meter, such as is used almost universally in this country, gets out of order either by something getting onto the valves, which prevents their sliding tightly and allows the gas to go by, in which case the register is against the company, or else by the diaphragm getting dry, in which case it registers against the consumer.

W. C. Parmley.—What is the serviceable life of a meter?

Mr. Greenough.—I think Mr. Beardslee charges off 10 per cent. of the value every year, but a meter ought to last much longer than that if it is in good condition. Many of these meters that are brought in and tested are just as good as they ever were. They seem to register just as accurately as the newer meters. A meter ought to last twenty years, but its length of life depends somewhat on the treatment it gets. The actual frame of a meter ought to last a long time, although the diaphragm might need replacing and fixing up a little.

R. L. Newman.—If it were possible, in a works burning probably 15 to 30 tons of coal a week, to draw further on the gas works and let them distil the gas for them and set it under the boiler, what would be the financial result to the corporation or company doing this? It seems to me the gas company would be in a better position to treat the gas than any one else. Some twelve years ago there was a large forge which used the ordinary coal gas from the town main, and when a large heat was on an exhauster was used that exhausted the gas and put out all the lights in that part of the town.

In a paper I once heard, the author said that the great objection to the use of water gas was its want of odor; that it was impossible to discover a leak. I would like to know whether the speaker knows any case where water gas alone was used, and whether it is possible to give it such an odor as would make it easy to discover a leak.

Mr. Greenough.—It would be impossible to answer in a moment the question as to whether it would be economy to use

gas from the mains under a boiler. The number of heat units in a thousand feet of gas is not over 700,000, and a ton of coal gives twenty-eight or twenty-nine millions, if I remember rightly. You could not use coal gas under a boiler with economy unless you could buy it for 5 or 10 cents. The economy of labor would be less than the additional cost. According to my calculations of last year, water gas would be worth about 3½ cents, and coal gas 5 cents; and the saving of labor might amount to 10 cents.

In some private establishments, where the actual cost of production is no object, and where high temperature and even flame are required, water gas is used. That use is attended with considerable danger, as there is a large amount of carbonic oxide in it and little smell. It is, however, being used with considerable success in this country in the welding of tubes and in making of saws, and it is used experimentally, in a comparatively small way through the town, in Bridgeport. It is sold there at from 25 to 15 cents, but so far no large business has been developed, because it costs too much for a large factory to use it, even at that price; and the company is paid too little for it to make it profitable. The distribution of artificial fuel gas I believe to be a dream. I do not think it can ever be done economically for large uses. For temporary use in a gas engine to run an elevator or something of that kind, coal gas, even at the price charged in this city, is most satisfactory, but under a boiler, never. Natural gas has about one thousand heat units. It was tried, I think, in the water works at Sandusky, but 7½ cents was thought too high, and the experiment was abandoned.

Mr. Roberts.—By way of confirmation of Mr. Newman's remark, I may mention that I had occasion to put electric lights in a gas plant, and it was found that the use of water gas was most unprofitable.

Mr. Newman.—I have noticed recently that large forges use gas in all their furnaces, manufacturing their own gas on the premises. There must, therefore, be some economy in this.

Prof. C. F. Mabery.—When I was in Cambridge, twenty years ago, the gas was from 15 to 16 candle-power, very irregular and very uncertain in its delivery. The gas we get in Cleveland is regular, is regularly 18 candle-power, as required, and gets up very well in its heating capacity. Gas here contains the full requirements of hydrogen, 35 to 40 per cent., and carbonic oxide, making an altogether excellent heating as well as illuminating gas. I think it is very much to be regretted that gas cannot be delivered for fuel in the dwellings. We shall have to

accept it as a fact that it never will be. If gas could be introduced into households to do away with the bother and expense of coal, it would be a great saving of labor and a great convenience in every way. But the cost of gas must be very low before it can compete successfully with coal. We can use it occasionally, and it has a very excellent heat capacity.

Mr. Greenough alluded to the uncertainty, in England, about the introduction of water gas. That may depend, to a certain extent, upon the hesitancy that people abroad have about anything that is popular in the United States. Analyses have not given precisely the same tests, and there seems to be some reluctance about producing it. In Cleveland we have been very fortunate about water gas. In 1884 a company proposed to furnish water gas at one-half the cost of ordinary illuminating gas, promising thereby to confer a great public boon. But the matter was warded off, and we are able to maintain excellent gas without competition.

Coal contains mostly compounds of carbon with hydrogen. It would be interesting to know how the hydrogen is combined with the carbon. When coal contains compounds of hydrogen with carbon, and nitrogen with hydrogen, destructive distillation goes on, and we get useful bi-products. Bi-products are coal tar and ammonia salts. Useful products are carbonic oxide, which is formed by the air coming into the pores of the retorts, combining with the carbon and hydrogen, which is the product of destructive distillation.

On motion of Mr. W. R. Warner, a vote of thanks was tendered to the speaker of the evening.

HISTORY OF THE STONE ARCH.

By Prof. Malverd A. Howe, Member Engineers' Club of St. Louis.

[Read before the Club, December 1, 1897.*]

The Century Dictionary defines the word "arch," in connection with architecture, as a "structure built of separate and inelastic blocks, assembled in such a way as to retain their position when the structure is supported extraneously only at its extremities."

According to this definition the arch must be very rare. In fact, it is doubtful whether it exists, as, up to the present day, physicists have been unable to find any inelastic substance from which to cut blocks.

Professor Greene, in his text-book entitled "Trusses and Arches," defined an arch as follows: "An arch may be considered to be any structure which, under the action of vertical forces, exerts horizontal or inclined forces against its supports or abutments."

It is to be noted that the particular form of the structure is not specified; and this is right, since, even in masonry structures where the true arch is employed, we have many different forms.

The primitive form of the arch was probably used over doorways or entrances in the form of two slabs of stone strutted against each other as the rafters in the modern roof. The earliest example of this form, of which we have any definite information, is that over the entrance to the great pyramid of Gizeh, constructed by Khufu some time between 3124 and 4235 B.C. (A photograph indicates that this is a true arch.)

Tuckerman, in his "Short History of Architecture," states that some of the chambers in this pyramid are roofed with slabs of stones inclined like rafters. The "Encyclopedia Britannica" makes no mention of this, but states that the third pyramid contains a chamber ceiled with a pointed arch, adding that this is not a true arch, the stones being merely strutted against each other, as over the entrance to the great pyramid, and that the underside is cut to the form of a pointed arch. In a small sketch, the "Encyclopedia" gives a cross-section of the vaulted chamber where the roof-stones are shown extending quite a distance into the masonry back of the side walls. If such is actually the condition, the roof is not a true arch, but an arched roof.

Crude arches of brick were found in the ruins of Thebes, which were probably built as early as 2900 B.C.

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*Manuscript received February 7, 1898.—Secretary, Ass'n of Eng. Socs.

Beneath the palaces of Nimrod (about 19 miles below Nineveh, on the left bank of the Tigris river), the ancient Calah, founded 1300 B.C., sewers were found covered with pointed arches of brick.

These arches, contrary to the usual form of to-day, were inclined, and could have been constructed without the use of a form for their support during construction.

The gates to an ancient city in Assyria, now represented by the ruins of Khorsabad, were arched with semicircular voussoir arches of stone, having spans of from 12 to 15 feet. These are

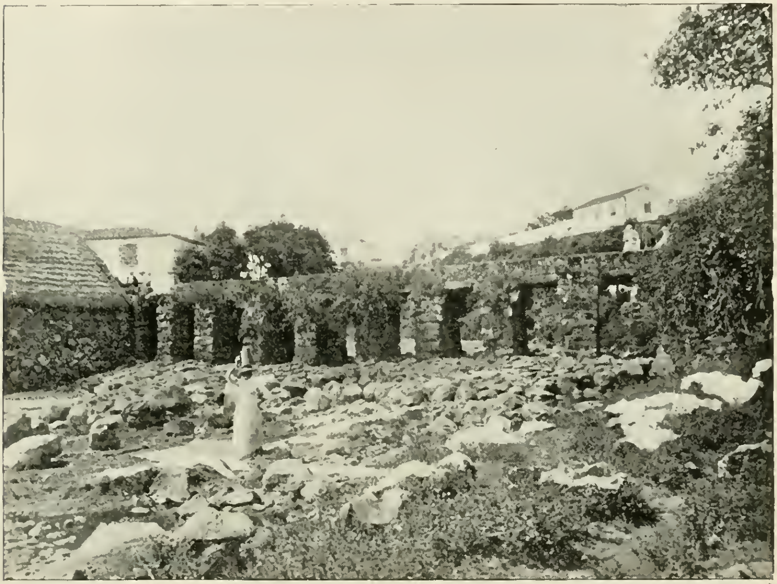

FIG. 1. VALLEY OF FLEMENGOS, FAYAL, AZORES.

supposed to date as early as the time of Sargon, who founded the city about 722-705 B.C.

One of the most important of the ancient structures in connection with the history of the stone arch is Campbell's tomb of Gizeh, supposed to have been built 600 B.C. "It is an open excavation, 53 feet 6 inches deep, 30 feet by 26 feet 3 inches on plan, with niches, etc., leading out of it. This excavation is supposed, from some indications left of a springing stone, to have been covered by an arch. If so, this would be the oldest known stone arch of a large size. In fact, it is difficult to imagine any other way in which this large excavation could have been covered."

Fig. 2. Cloaca Maxima, Rome, Italy.

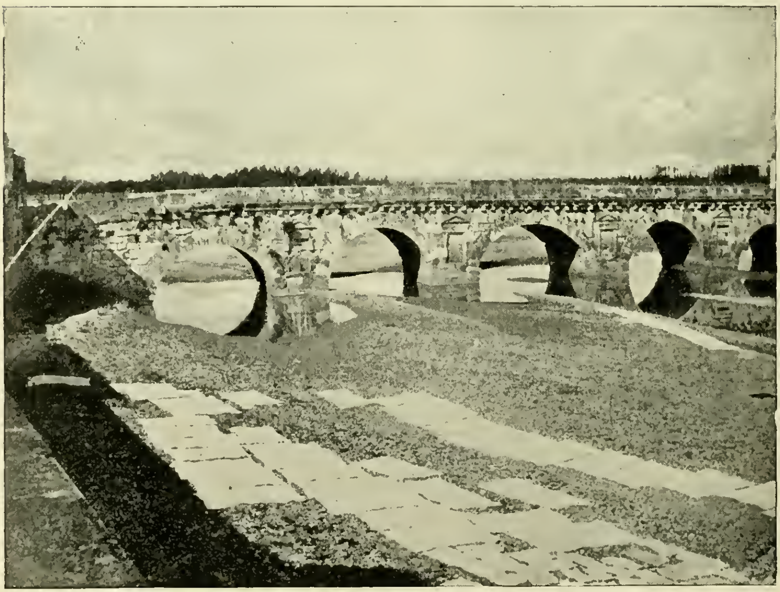

Fig. 3. Bridge of Augustus, Rimini, Italy.

But more interesting and important than this was the tomb, built of good masonry, which was found in the center of "the excavation." The roof was formed of three stones forming a true arch, over which was a perfectly formed voussoired arch of four distinct rings, the inner ring having a span of about 11 feet. These arches were nearly, if not quite, semicircular.

At about this time the Romans commenced the use of the voussoired arch, as witnessed by the outlet of the Cloaca Maxima, supposed to have been built 615 B.C. (Fig. 2). The arch consists of three concentric rings of voussoirs, the inner ring having a span of about 14 feet.

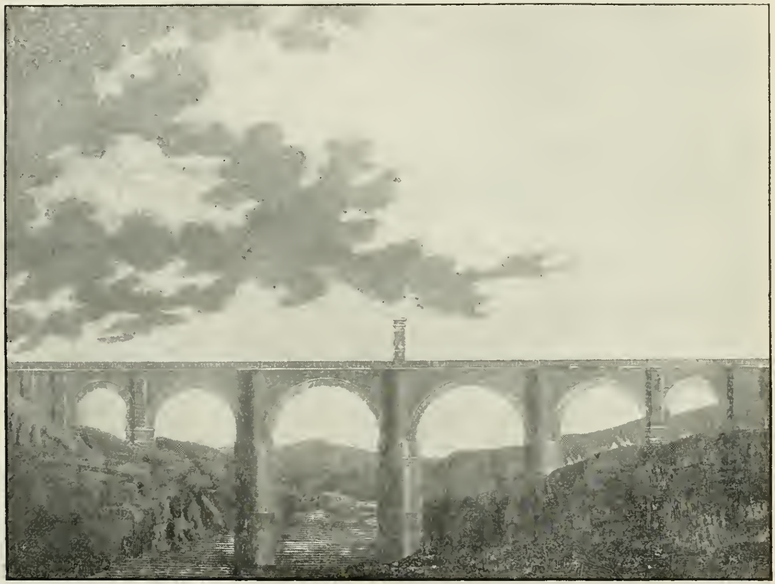

FIG. 4. OLD STONE BRIDGE AT ALCANTARA, SPAIN (105 A.D.)

All records in the form of ruins, tablets, etc., fail to indicate that the true arch was employed in structures to any great extent prior to the sixth century B.C. The arched form, however, was quite common from earliest times, and ruins have been found in all portions of the world.*

One of the best examples of the false arch exists in Greece. It was built probably as early as 1000 B.C. This is the Treasury of Atreus at Mycenæ, which consists of two underground chambers, one much larger than the other. The larger chamber is

*Quite recently a voussoired arch of mud brick was discovered at Nippur (Fig. 26). The date of its construction is placed at about 4000 B.C.

Fig. 5. St. Angelo, Rome, Italy.

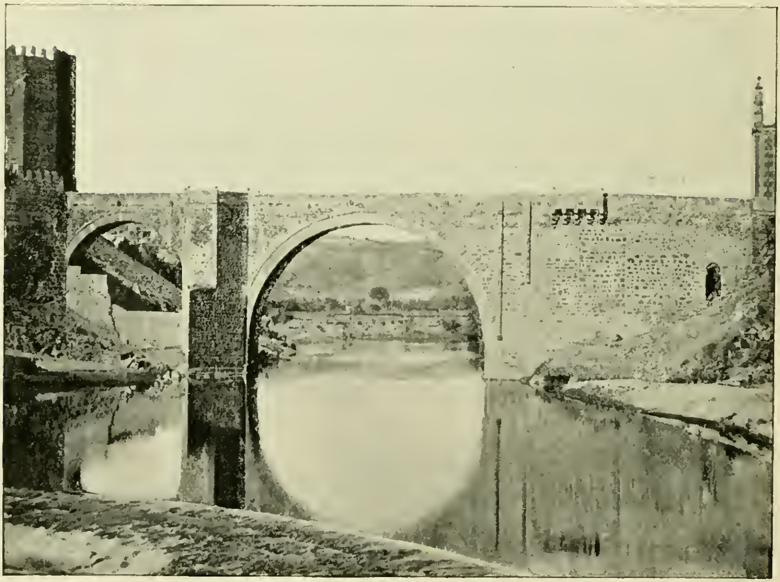

Fig. 6. Bridge Alcantara, Toledo, Spain.

circular, and is entered by a huge doorway at the end of a long avenue.

The internal form is that of an immense lime kiln. The masonry consists of horizontal projecting courses of stone, the inner projecting corners being cut off.

The arched form does not prove that the builder was familiar with the true arch, but the manner in which the horizontal courses are constructed clearly indicates that he had some idea of the true arch, as either each stone is cut wedge-shape, like voussoirs in a vertical arch, or the joints are tightly wedged with small stones.

FIG. 7. BRIG O'BALGOWNIE, ABERDEEN, SCOTLAND.

The internal diameter of the chamber at the base is 48 feet 6 inches, and the clear height 45 feet.

In Asia Minor tombs were found having arched roofs made by corbelling out horizontal courses of stone until they met at the top, and then cutting off the projecting edges underneath. Lübke, in his "History of Architecture," states that these were probably constructed as early as 700 B.C.

The arch was first used by the Romans for the construction of stone bridges in the second century B.C., though stone was probably employed for this purpose much earlier. The early stone bridges were constructed by building piers in the stream so close

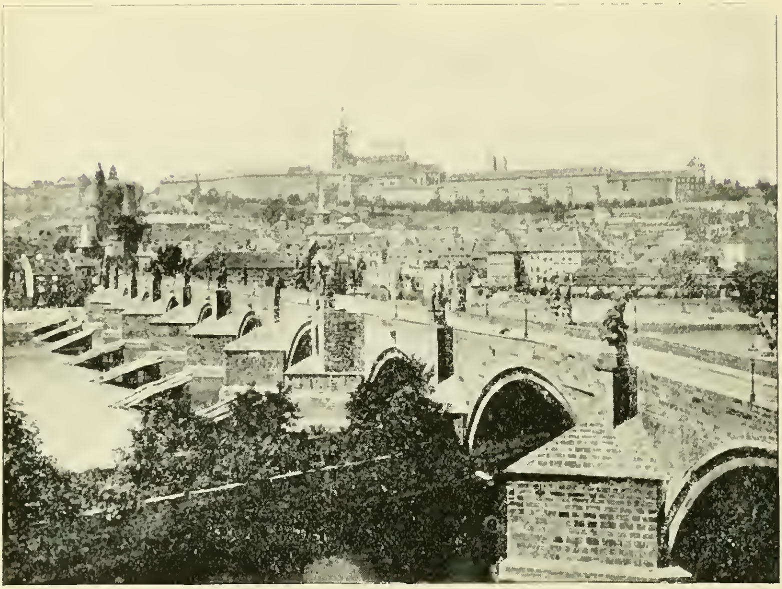

Fig. 8. Karlsbrucke over Moldau, Prague, Austria.

Fig. 9. Vecchio Bridge, Florence, Italy.

together that the opening could be spanned by stone beams. (Fig. 1 shows this style of construction.)

The bridge over the Euphrates river at Babylon was probably built in this manner.

There are a large number of examples of the true arch in bridge construction in China, as well as the primitive form of stone bridges without arches. The date at which these bridges were constructed is unknown, but many believe that the Chinese built the true arch long before it was known to the western world.

There is an account of a bridge over a river named Laffranyi, China, connecting two mountains. The bridge is said to be of

FIG. 10. RIALTO, VENICE, ITALY.

one arch of stone, having a span of 600 feet and a height of 750 feet ("Edinburgh Encyclopedia"). The authority for this account is not authentic, and, although a stone bridge of such magnitude is not impossible from the engineer's point of view, it is yet improbable.

The old voussoired arch bridges of the Chinese are interesting from a peculiarity of the arch ring. "Each stone from 5 to 10 feet in length is cut so as to form the segment of the arch, and in such cases there is no keystone; ribs of wood fitted to the convexity of the arch are bolted through the stones by iron bars fixed into the solid part of the bridge; sometimes they are without wood, and

the curved stones are mortised into long transverse blocks of stone."

The details of the more modern Chinese arches do not differ essentially from those employed in other countries.

To the Romans we are indebted for the almost universal use of the voussoired semicircular arch in bridge construction. From the second century B.C. until the fourth century A.D. the Romans built many magnificent stone arch bridges for roads and

FIG. 11. FLEISCH-BRUCKE, NUREMBURG.

aqueducts, the magnitude of which has not since been equalled. It would take too much time to enumerate the many bridges in Rome and in the conquered provinces which were constructed by the Romans, and of which we have either authentic details or the structure itself, so we will mention only a few of the most important structures.

In the city of Rome and in the immediate vicinity were constructed aqueduct bridges containing immense amounts of

masonry, and throughout these the voussoir arch was employed. The following table gives, in the chronological order of their construction, the number of miles of arches used in supporting aqueducts. (Mr. F. W. Blackford, in JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES, December, 1896):

Name.	Date.	Total length in miles.	Length of arches in miles.
	B. C.		
Appia	312	11	Little
Anio Vetus	272–264	43	"
Marcia	145	61	12
Hercules bridge		3	
Tepula	126	13	Little
Julia	34	15	6
Virgo	21	14	Little
	A. D.		
Alsientina	10	22	Little
Augusta	10	6	"
Claudia	50	46	10
Anio Novus	52	58	9
Neronian bridge	97	2	2
Triana	109	42	Little
Hadriana	117	15	7
Sabina Augusta	130	15	Little
Aurelia	162	16	*7
Severiana	200	10	Unknown
Antoniana bridge	215	3	3
Alexandrina	226	15	†7
Totals		410	63

Remarks: * Restored 1585–1590.
† On arches of Hadrian.

From this it is seen that between 312 B.C. and 226 A.D. sixty-three miles of arch bridges were built.

Pont du Gard, near Nimes, France, was built by the Romans during the reign of Augustus (27 B.C.-14 A.D.) under the direction of Agrippa. This is an aqueduct bridge composed of three tiers of arches. The lower tier contains six arches. The maximum span is 80 feet 5 inches. Each arch is made up of four separate rings, side by side, and not bonded together. The platform of this tier is 20 feet 9 inches wide. The second tier contains 12 arches of about the same span as those in the lower tier, but has only three rings side by side, and is but 15 feet wide. The upper tier contains thirty-six arches, each having a span of 15 feet 9 inches, and is 11 feet 9 inches wide on top. The aqueduct channel is about 4 feet 9 inches deep and 4 feet wide. At the beginning of the fifth century the ends were destroyed by barbarians. In 1743 the bridge was repaired, and the lower tier widened to carry a highway. The maximum height of the bridge above the river Gardon, which it crosses, is 160 feet.

Emperor Augustus constructed a beautiful stone bridge over

the river Marecchia, at Rimini, Italy (Fig. 3). It consists of five semicircular arches having a span of 23 feet. This bridge is in use at the present day, and from all appearances has required but few repairs.

The most magnificent bridge built by the Romans was constructed in the reign of Augustus near Narni, Italy. It consisted of four arches having spars of 75, 135, 114 and 142 feet respectively.

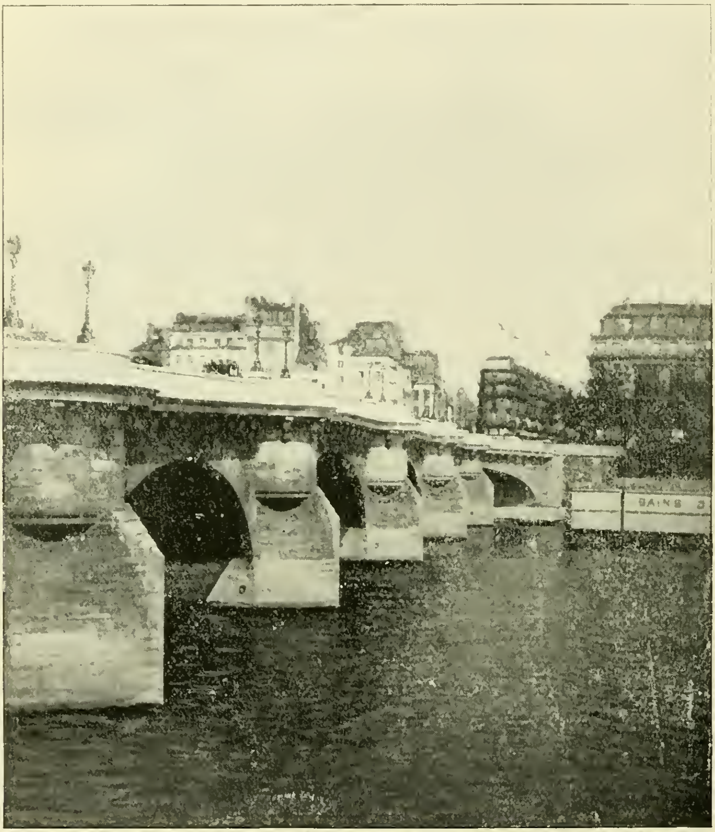

Fig. 12. Pont Neuf, Paris, France.

About 104 A.D., during the reign of Trajan, the aqueduct bridge at Segovia, Spain, was built. The bridge contains 109 arches in two tiers. Thirty of the arches are modern, but similar to the old ones. The length of the bridge is over 2500 feet. The three center arches are 102 feet high. The entire structure is built of squared granite blocks, without mortar. During this same period Trajan constructed a fine stone bridge over the

Tagus river at Alcantara, Spain (Fig. 4). There were six semicircular arches of various spans, the maximum being about 100 feet. The total length of the bridge was 670 feet, and the maximum height above the river was 210 feet. The material was granite, laid without mortar. The bridge was in use until 1809, when the English destroyed the second arch on the right bank of the river. This was temporarily repaired, but again destroyed in 1836, since when no repairs have been made, the natives using a ferryboat to cross the stream.

In 135 A.D., during the reign of Hadrian, the bridge now called St. Angelo was built at Rome (Fig. 5). It consists of four

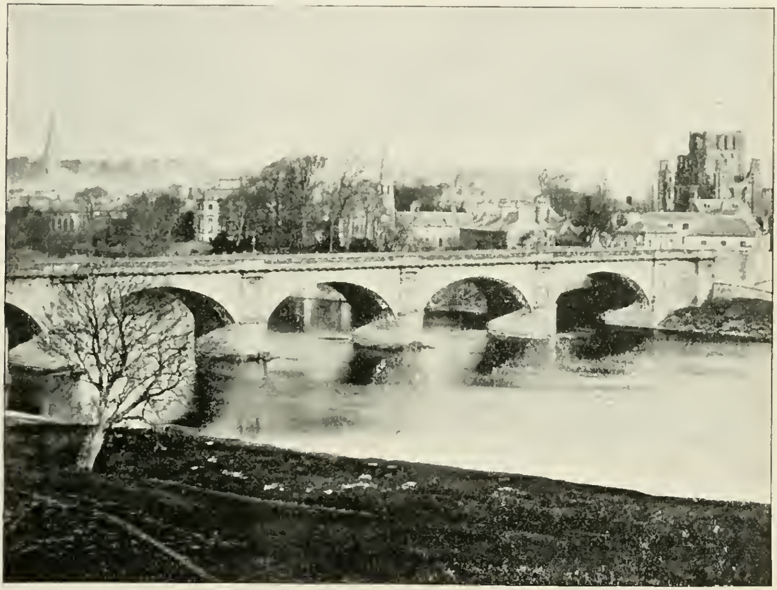

Fig. 13. Kelso Bridge, Kelso, Scotland.

circular arches, the span of the largest being 62 feet 4 inches. This structure is supposed to have been covered with a roof of bronze, supported by forty-two columns. It was repaired by Popes Nicholas III. and Clement IX.

The present balustrade, statues, etc., are, of course, recent, but the arches are old. In nearly all of the Roman bridges the arch was semicircular in form, and although the segmental and pointed forms may have been known they were never employed in the construction of bridges. The spans of the arches were usually small in comparison with a few of our modern structures, yet they successfully built bridges with spans of 142 feet, which is exceeded

Fig. 14. Dunkeld Bridge, Dunkeld, Scotland.

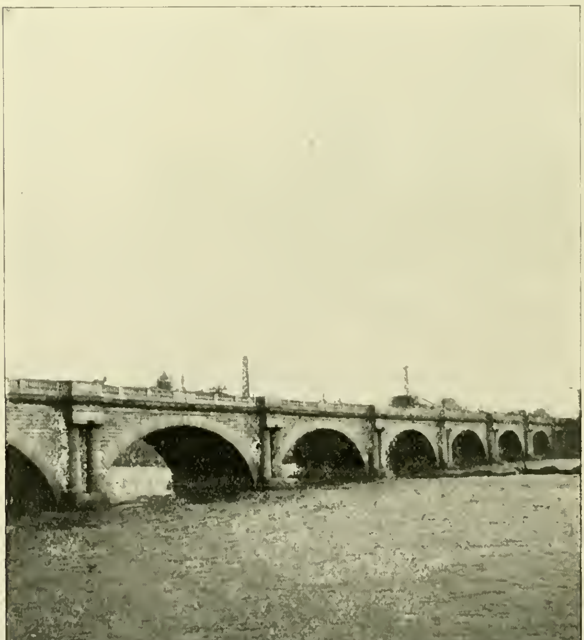

Fig. 15. Waterloo Bridge over Thames, London.

by but a small percentage of the structures built since the seventeenth century.

Another interesting fact in connection with the Roman bridges is that the centering was almost always supported upon large stones projecting from the piers below the springing line. These are clearly shown in photographs of the Pont du Gard and the aqueduct bridge near Segovia.

We come now to a period of several centuries in which little was done in bridge building or in keeping in repair the bridges already erected, though we may mention two bridges constructed by the Moors in Spain. At Cordova, about 912-916 (?), was built

FIG. 16. LONDON BRIDGE OVER THAMES.

a bridge of sixteen arches over the Guadalquiver. The style is a combination of the Roman and Moorish types.

In 997, at Toledo, Spain, the bridge Alcantara was built over the Tagus river (Fig. 6). It consists of practically two spans, the larger being 93 feet. The style of the structure is Roman and Moorish; the arches are semicircular, while the tower has the stamp of Moorish origin.

In the twelfth century the art of bridge building revived.

Owing to the destruction of many of the old Roman bridges and the unsettled condition of many districts, there was little "security for travelers, particularly in passing rivers, where violent

Fig. 17. Bromielau Bridge, Glasgow, Scotland.

Fig. 18. Waldi-Tobel Bridge near Bludenz, Austria (Railway).

exactions were made by banditti." "To put a stop to these disorders, sundry persons formed themselves into fraternities, which became a religious order, under the title of 'Brothers of the Bridge.' The object of this institution was to build bridges, ferry boats and receive travelers in the hospitals on the shores of rivers."

The first established was upon the Durance, at a dangerous place named Maupas; but in consequence of the accommodations arising from the establishment, the same place acquired the name of Bonpas. St. Benezet, who proposed and directed the building of the bridge of Avignon, was a shepherd, and was not twelve years of age when he received revelations from heaven commanding him

Fig. 19. Elyria, Ohio.

to quit his flock and undertake this enterprise. He arrived at Avignon just at the time when the bishop was preaching to fortify the minds of the people against an eclipse of the sun, which was to happen upon that day. Benezet raised his voice in the church, and said he had come to build a bridge. His proposition was accepted by the people with applause, but rejected with contempt by the magistrates and by those who thought themselves wisest. As it was at this time an act of piety to build bridges, and Avignon being then a popular republic, the people prevailed, and every one contributed to the good work; some by money and some by labor, all under the direction of Benezet, aided by the Brothers. St.

Benezet, by performing a great number of miracles, animated the zeal of everybody. Upon the third pier was erected a chapel to St. Nicholas, protector of those who navigate rivers. This was done, however, after the death of St. Benezet, which happened in 1184 ("Edinburgh Encyclopedia").

This bridge, which was composed of eighteen or twenty-one arches, was begun in 1176 and completed in 1188. In 1385 Pope Boniface IX. destroyed some of the arches. In 1410 the inhabitants blew up a tower, causing the fall of three spans. In 1670 the cold was so severe that the Rhone for several weeks bore the heaviest carriages; when the thaw followed the ice destroyed the piers; but the third pier, with the chapel of St. Nicholas, has remained, notwithstanding these many accidents. The span of

Fig. 20. Main Street, Wheeling, W. Va.

the largest arch was about 102.9 feet, and was semicircular. (Authorities differ here, some claiming that the arch had a span of 110 feet and was segmental. The "Encyclopedia Britannica" states that the arches were elliptical, the minimum radius of curvature being at the crown.)

In 1176, or practically at the time when the bridge at Avignon was commenced, Peter of Colchester, a priest, began the erection of the old London bridge across the Thames, but the structure was not completed until 1209. The bridge originally contained nineteen pointed arches having spans from 9 to 20 feet, and piers 25 to 34 feet thick.

For many years there were houses along each side, but these

were removed in 1758, and the middle pier and two arches replaced by a single arch of 72 feet span. In 1824-31 the new London bridge replaced this structure.

In 1203 the bridge St. Martin was built over the Tagus river at Toledo, Spain. It consists of five arches, the center arch being the largest, with a span of 132 feet. This arch is very slightly pointed.

In 1281 the Brig O'Balgownie was built over the river Don on the road leading from the old to the new town of Aberdeen, Scotland (Fig. 7). This bridge contains but one arch, which is pointed, and has a span of 66 feet.

Fig. 21. Jaremcze Bridge over Pruth, Austria (Railway).

These bridges with pointed arches, constructed in different countries, place the introduction of such arches in bridge building at about the thirteenth century.

The old Charles bridge over the Moldau, Prague, Austria, was built between 1357 and 1507 (Fig. 8). It consisted of sixteen spans, the largest being 69.5 feet. In a photograph the arches appear to be semicircular. The structure was ornamented with thirty statues and groups of saints, one of which is a bronze statue of St. John Nepomac, patron saint of Bohemia (in whose memory the bridge is visited yearly by thousands of pilgrims). The saint is said to have been flung from the bridge in 1383 by order of the

13

Emperor for refusing to betray the confessions of the Empress. The body is said to have floated for some time with five brilliant stars hovering over the head. The bridge was partially destroyed by a flood in 1890.

In 1380 a very large arch was built over the Adda river near Trezzo, Italy, by order of Visconti, but was destroyed by Carmagnola in 1416. From the ruins which remained in 1838 (about 20 feet at each abutment) the span has been determined to have been about 251 feet and the rise about 88 feet. The arch ring was remarkable as being in two concentric rings with a total thickness of but 4 feet.

Fig. 22. Cresheim Bridge, Philadelphia, Pa.

The Vecchio bridge at Florence, Italy (Fig. 9), over the Arno river, was first built in 1177, but was rebuilt in 1345. It consists of three arches of 96 feet span and 19.2 feet rise, the curves being segments of a circle and in appearance quite flat. The width of the structure is 105 feet, and along the sides are built stores, etc.

Adjacent to the Vecchio bridge, the Trinity bridge was erected in 1566. It consists of three elliptical arches, the largest having a span of 95.8 feet and a rise of 16 feet.

The Rialto at Venice, Italy, built of marble in 1588-91, has but one span of 98.5 feet, with a rise of 23 feet (Fig. 10).

Apparently in imitation of the Rialto, the Fleisch-brücke in Nuremburg was constructed in 1599, with a span of 97 feet and a rise of 13 feet (Fig. 11).

These examples of the segmental, or elliptical, arch mark the advent of flat arches, though, of course, the form was not universally employed, as Pont Neuf, over the Seine river, Paris, France (Fig. 12), built between 1578 and 1604, consists of a large number of nearly semi-circular arches with a maximum span of 51.1 feet and a rise of 21.9 feet.

In 1553-1570 the Tempoala aqueduct, seven miles south of Huauchinango, Mexico, was constructed under the direction of a

FIG. 23. LODI STREET, ELYRIA, OHIO.

Franciscan friar. It contains sixty-eight semicircular arches, the largest having a span of 58 feet. Its maximum height is 124 feet. It is built on two tangents 177 degrees apart. The waterway is only 8½ inches by 12 inches.

During the eighteenth century many fine bridges were built. Of these only a few can be mentioned. Near Lisbon, Spain, the Alcantara aqueduct was commenced in 1731 and completed about 1774. It contains thirty-five pointed arches, the largest arch having a span of 100 feet and a rise of 88 feet. The height of the intrados of the maximum arch is 197 feet, while the maximum height of the bridge is 230 feet.

It is claimed that this is the highest masonry arch bridge, having but one tier of arches, in the world.

Pont-de-la-Concorde (built 1787), at Paris, France, has five segmental arches, the center span being 102.3 feet with a rise of 9.8 feet.

The Kelso bridge over the Tweed river, Kelso, Scotland (Fig. 13), was built 1799-1803. It has five elliptical arches with a maximum span of 73 feet and a rise of 21 feet.

In 1809 the Dunkeld bridge over the Tay river, at Dunkeld, Scotland, was completed (Fig. 14). There are seven arches, the center span being 90 feet with a rise of 30 feet.

Fig. 24. Echo Bridge, Boston, Mass.

Between 1813 and 1822 a fine bridge over the Garonne river, at Bordeaux, France, was built. There are seventeen elliptical arches, having spans varying from 65.86 feet to 86.92 feet. The maximum span has a rise of 28.9 feet.

The new Waterloo bridge, London, was opened in 1817 (Fig. 15). There are nine elliptical arches, with a span of 120 feet and a rise of 34.6 feet.

The new London bridge was built between 1821 and 1830. (Fig. 16.) The five elliptical arches have spans varying from 130 feet to 152 feet. The rise of the maximum span is 29.6 feet above high water.

The Bromielaw bridge, in Glasgow, Scotland (Fig. 17), has seven segmental arches, the largest having a span of 58.5 feet with a rise of 10.8 feet. It was constructed 1833-36.

In 1841-47 the highest stone bridge in the world was constructed on the canal leading to Marseilles, France, where it crosses the Arc Valley. The bridge has three tiers of arches. The lowest tier has twelve arches of 49.2 feet span; the middle tier fifteen arches of 52.5 feet, and the upper tier fifty-three arches of 16.4 feet span.

The bridge if 48 feet wide on top, 1289 feet long and 271 feet high. The width of the canal on the bottom is about 22 feet.

FIG. 25. WISSAHICKON BRIDGE, PHILADELPHIA, PA.

Up to 1847 nothing of any magnitude, in the way of stone bridges, had been erected in the United States. During this year the Starrucca viaduct, carrying two tracks of the New York, Lake Erie and Western Railway, over Starrucca creek, near Lanesborough, Pa., was constructed. There are seven segmental arches of 51 feet span, and the maximum height of the rails above water is 110 feet.

In 1852-59 the Cabin John bridge, the largest stone arch in the world, was built, near Washington, D. C., to carry an aqueduct

and highway over Rock creek. Its span is 220 feet, with a rise of 57.3 feet.

The Waldi-tobel* bridge, in the western part of Austria, was built in 1884 (Fig. 18). Its span is 134.5 feet, with a rise of 42.16 feet, while the rails are about 160 feet above the bottom of the gorge which it crosses.

In 1884 a highway bridge, with a span of 150 feet and a rise of 27 feet, was built at Elyria, Ohio (Fig. 19).

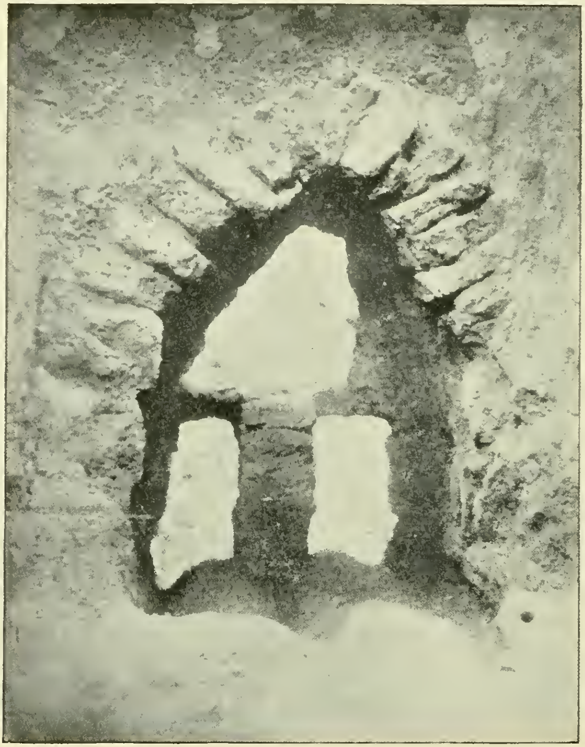

Fig. 26. Babylonian Arch of Brick at Nippur.

In 1892, at Wheeling, W. Va., an arch with a span of 159 feet and a rise of 28.4 feet was constructed (Fig. 20).

In this year (1892) the Jaremze* bridge, the largest arch bridge in the world for railway purposes, was built in the eastern part of Austria over the river Pruth (Fig. 21). The span is 213 feet and the rise 59 feet.

*This bridge was designed by Mr. Ludwig Huss, chief engineer of the Austrian State Railways, to whom the author is indebted for the photograph.

The Cresheim bridge, in Fairmount Park, Philadelphia, Pa., built in 1892, has a span of 116 feet, with a rise of 21.1 feet (Fig. 22). This bridge carries a sewer over a small stream.

The Lodi street bridge, at Elyria, Ohio, has a span of 112 feet and a rise of 19.5 feet. It was built in 1894 (Fig. 23).

Probably the most pleasing stone bridge, from an architectural point of view, is the Echo bridge, at Newton Upper Falls, Mass. (Fig. 24). It has a span of 129 feet and a rise of about 27 feet. It carries an aqueduct and highway, and was built in 1894.

*During the present year a very artistic highway bridge has been built in Fairmount Park, Philadelphia, Pa (Fig. 25). The span is 105 feet, with a rise of 11.0 feet.

The examples of stone arch bridges given above are, of course, but a very small percentage of those which have been constructed. With but a few exceptions, only those structures have been mentioned concerning which the data are believed to be authentic, and of which photographs could be obtained.

Data concerning even the more modern structures are very hard to obtain, and in many cases it is practically impossible to purchase photographs.

The following conclusions may be drawn from the above data:

The Romans first used the arch in the construction of bridges in the second century B.C.

Until about the thirteenth century the arch in bridges was of the circular form, and almost without exception it was semicircular.

The pointed arch was first employed in bridges about the thirteenth century.

In the fourteenth century segmental and elliptical arches were introduced.

At the present time the segmental arch is almost universally employed for long spans.

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*Through the courtesy of Mr. John C. Trautwine, Jr., the author obtained photographs of this bridge.

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THE ERECTION OF METALLIC BRIDGES.

BY FRANK P. MCKIBBEN, MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Society, December 15, 1897.*]

WHEN we consider the short length of time required to erect an ordinary pin-connected bridge, and the comparatively small number of men employed in such an undertaking, we are more nearly capable of realizing that the construction of those marvelous works of engineering, the pyramids of Egypt, is not among the impossibilities of the present day. When we think of these wonderful ancient structures, some of which consist of a mass of stone weighing six or seven million tons, we do not always associate with them the thought that they represent the energy of tens of thousands of men employed for fifteen or twenty years. Likewise, when we view such structures as the beautiful suspension bridge at New York or the awe-inspiring span over the Forth, we do not always realize how short a time is consumed in erecting the superstructures of such works. The rapidity with which many of our long-span railroad bridges are placed upon their masonry supports is little short of marvelous. Possibly the Cairo bridge, which spans the Ohio river in Southern Illinois, is one of the best examples of how our skilled workmen can elevate heavy pieces of steel, weighing perhaps 20 or 25 tons, into their correct positions, adding piece after piece until the span is self-supporting. One span of this structure, weighing about 2,000,000 pounds and meas-

*Manuscript received March 5, 1898.—Secretary, Ass'n of Eng. Socs.

uring 518 ft. 6 in. center to center of end pins, was erected in six days. To erect the entire superstructure of two spans of this length required the services of seventy-five men working one month and three days. This includes five days of idle time, and also the time necessary to move the false-work from one span to the other. At the present time it is perfectly safe to say that after the false-work has been placed in position it is possible to erect within one day pin-connected bridge trusses of spans not exceeding 200 feet.

What has made possible this rapidity of erection? It is due, first of all, to the adoption of the so-called American type of pin-connected truss, which is the result of the inventive genius of the American bridge engineer. To be able to place a steel span upon its piers in a minimum amount of time in order to reduce liability of damage from floods, ice jams, etc., and at the same time have a joint as nearly perfect as possible, has been the problem. How the pin-connected truss has enabled erectors to accomplish this is shown by the example just cited. For our large and swift rivers subject to sudden floods that bridge is preferable which can be quickly made self-supporting, thereby reducing to a minimum the risk of a washout during erection. The pin-connected truss surely possesses in this respect a marked advantage over the riveted type. There are, however, cases where the latter is preferable. A pin-connected truss bridge can be erected so as to permit the passage of trains without driving a single rivet at the site of erection. The only field-driven rivets in such a bridge are those which connect the top chord pieces at the splices, the lateral bracing and the floor system. Bolts may temporarily be used in such places and the bridge made capable of carrying a train of cars in a very short time. This rapidity of erection not only avoids danger from washouts, but in the case of a renewal of an old bridge it reduces to a minimum the interference with the passage of trains, which on most railroads is a very important matter. The bolts which temporarily serve their purpose are replaced by rivets after the bridge is entirely free from the false-work. Such a procedure as here outlined would be employed only in extraordinary cases.

In the design of a bridge care must be taken to introduce all features which will aid in the rapid assembling of parts in the field, and to avoid all possible interference of one member with another. For instance, the rivets in the top chord at its intersection with the end-post must be carefully studied to avoid any interference. If a rivet head is left in such a position as to prevent the connection of the various members which meet at the joint, the erection of the

structure is brought to a standstill while the rivet head is chipped off. A few moments' careful study of the rivets would prevent such a delay, and save the contractor for erection a considerable sum of money. The importance of the careful investigation of the method of erection will be shown later in connection with the construction of cantilever bridges. It will then be seen that some very peculiar details are introduced into the design of this form of truss to facilitate the final adjustment and connection at the center of the suspended span.

Let us now consider the various methods of erecting different forms of metallic bridges, beginning with the simplest, namely, the short span "I" beam bridge. Such a structure is nearly always sent from the bridge shop in one piece, ready to be placed on the abutments without any field riveting. Inasmuch as "I" beams are rarely used for spans of more than 18 or 20 feet, the means employed for handling them in the field are very simple. If a railway bridge is to be built over a roadway, and is not more than 20 or 30 feet above the latter, a derrick may be set up on the surface of the roadway and the structure lifted from a car directly onto the abutments. Or, the derrick may be set up on the surface of the railway embankment instead of on the lower level. In case the bridge spans a small stream, the derrick would of course be used as last suggested. Frequently instead of the derrick the railway or bridge company makes use of a crane fixed upon the end of a platform car. For light "I" beam or plate girder bridges the derrick or crane is very expeditious, but when the weight becomes too great to be handled readily in this way, or when neither of these appliances is at hand, the erection may be accomplished in the following manner.

If the road is a new one, the car on which the bridge is carried may be run up to the opening to be spanned and the girders skidded across on wooden beams inclined from the car to the opposite bridge seat. The wooden beams are then removed and the bridge is lowered onto the abutments. After the steel work is thus placed in position the track is laid and the bridge is ready for traffic. If the girders and lateral bracings have been sent from the shop as separate pieces, the girders may be skidded across on wooden beams as before, and then lowered onto the masonry supports. The laterals are then riveted in and the steel work is finished. On the other hand, if the opening is already spanned by a structure which is to be renewed, then the entire bridge, including the lateral bracing, may be riveted together, near the site, and at some convenient time between trains placed on a dolly car and

moved up to the opening. The old bridge is then torn out and the new one skidded across the opening as before explained. The method here merely outlined may be used very effectively for "I" beam or plate girder bridges of spans not exceeding 25 feet. Ordinarily it would be more economical than that method in which a derrick or crane is employed, and almost as expeditious. In case the interruption of traffic will not permit the removal of the track even for a very short length of time, the girders could be placed across the opening and set upright just outside of the old girders. The new ones could then be moved laterally under the track and the old beams removed. This method of procedure, in general applicable to deck spans only, would not interfere with traffic in the least.

For plate girder spans exceeding 25 feet the girders are generally too heavy to be erected by use of the preceding methods. However, by building one, two or three trestle bents under the wooden beams these will be strengthened so that the girders may be launched out as previously suggested for the shorter spans. These heavy girders should be skidded out lying flat, so as to avoid accidents by overturning. It will be noticed that this method differs from that used for the shorter spans in that the false-work is used to aid in supporting the girders.

A very simple method of placing the two girders upon the abutments at the same time is as follows: one or more timbers are laid across each end of a platform car so that the girders may be suspended from the projecting ends of the beams. The car carrying a girder on each side is then run out onto the false-work, or onto the old bridge, as the case may be, and the girders lowered into position.

Plate girders are frequently erected by means of a gin-pole, which usually is a single mast guyed at the top. This pole is raised at the side of the track so that by means of a hoist line which passes over a sheave at the top the girder may be raised and placed in position. Frequently only one gin-pole is necessary, but sometimes two or even three are used. These poles are not placed vertical, but are inclined so that the upper end overhangs the piece to be raised. By tightening or loosening the guys the position of the load may be regulated. The hoist line, after passing over the sheave at the top of the pole, runs to a "crab," or windlass, near the bottom. Recently in erecting bridges on the New York, New Haven and Hartford Railroad by means of gin-poles the hoist lines were run through pulley blocks at the foot of the poles and then to locomotives, which furnished the power necessary to raise the

girders. Fig. 1 illustrates a gin-pole used in erecting a 25-ton girder in Minneapolis. In this case a locomotive furnished the power for hoisting. The gin-pole itself is usually raised with a derrick or an "A" frame. Such poles have been used to a length of 146 feet, and, for the shorter lengths, are a single pole or mast. In the erection of the water tower at Montezuma, Iowa, a pole was used which was 114 feet long and 4 feet square, built up of 4"x4" pine timbers and latticed with planks. Fig. 2 shows the framed 146-foot pole used in erecting the tower of a lift-bridge at Manitowoc, Wisconsin. This is the tallest gin-pole on record.

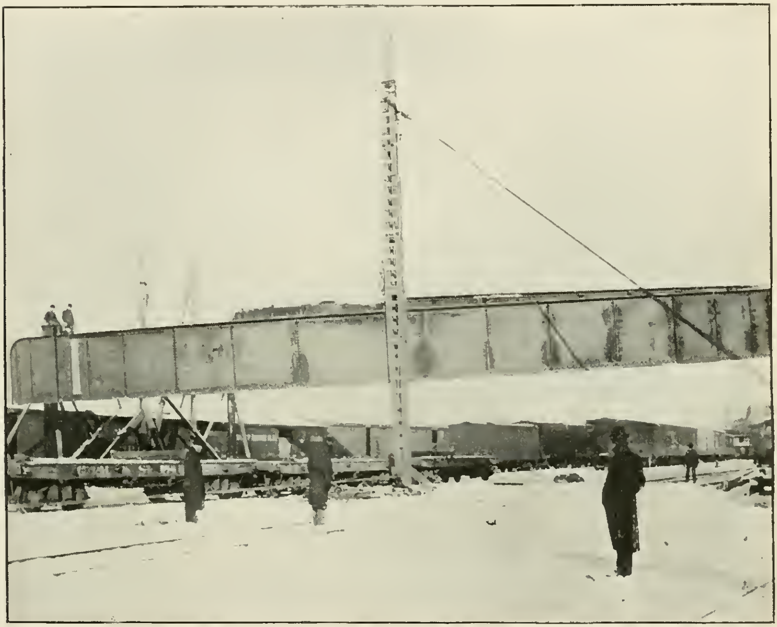

FIG. 1. HOISTING 25-TON GIRDER WITH GIN-POLE AND LOCOMOTIVE, MINNEAPOLIS, MINN., 1896.

Let us now consider some of the methods both usual and unusual for handling the long-span plate girders such as that illustrated in Fig. 3. This view shows a plate girder 123 feet long, 10 feet high and weighing 50 tons, which was constructed in Pittsburg for a bridge at the junction of two streets in Philadelphia. Before proceeding further with the erection of this bridge, permit me to speak of the importance of the careful loading of plate or lattice girders on cars for transportation. Girders are sometimes laid flat upon the cars and sometimes set upright, as shown in Fig. 3. When the latter method is used the girder rides the curves of the

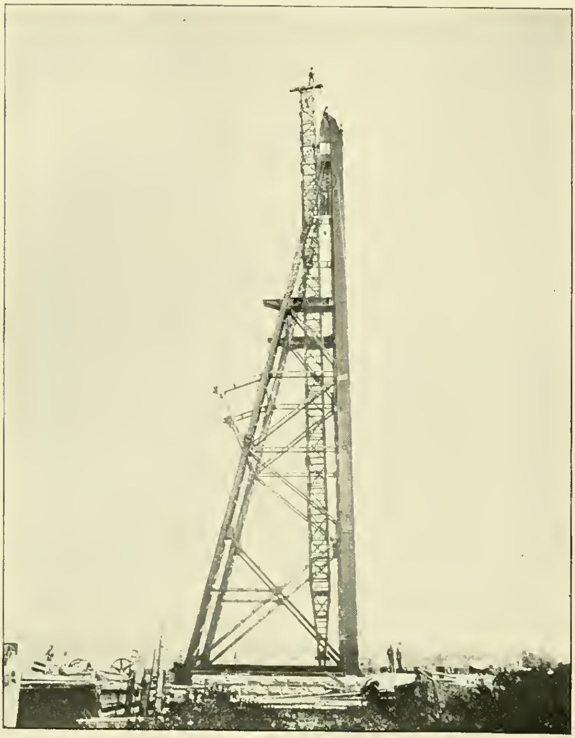

FIG. 2. HIGHEST GIN-POLE ON RECORD.

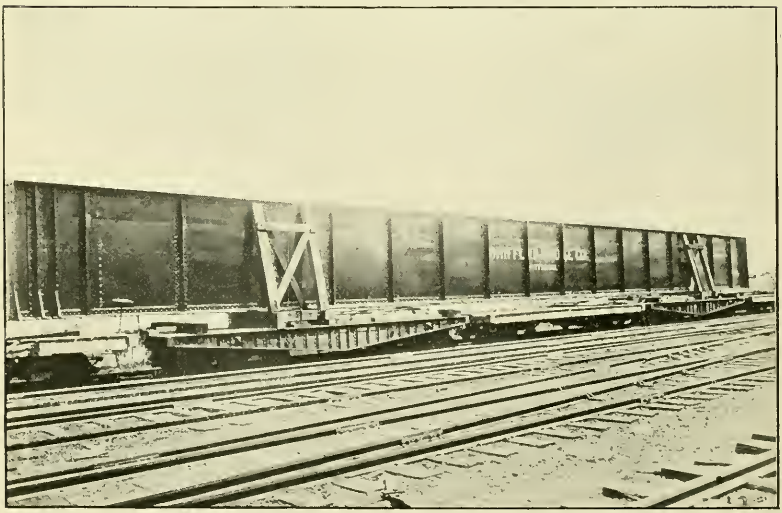

FIG. 3. 123-FOOT GIRDER, PHILADELPHIA.

railway track with great ease, but there is a risk of overturning which we do not have if the girder is laid on its side. Fig. 3 shows the manner of loading this 123-foot girder for transportation from Pittsburg to Philadelphia. Of the five cars used three were idlers. The cars which supported the girder were gun-trucks, and each end of the girder was supported on and rigidly attached to a pivot frame, thus enabling the girder to move freely when riding around the curves. Provision was also made for the longitudinal slipping either at one or at both ends. To prevent overturning the frames were constructed as shown in the cut. Also to lower the center of gravity of the cars and girder, the former were loaded with pig

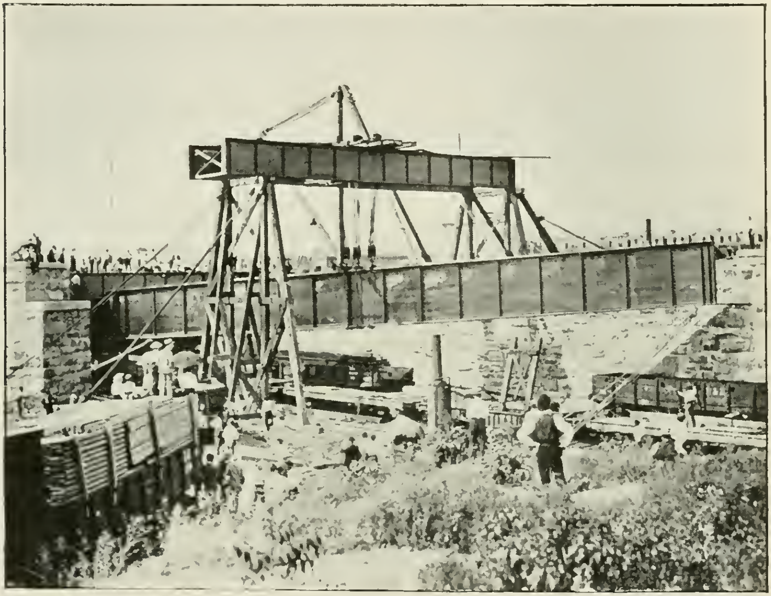

Fig. 4. Shiffler Bridge Company, 123-Foot Span in Philadelphia.

iron. On account of the great depth and length of the girder it was found to be impossible to transport the load directly over the main line of the Pennsylvania Railroad. A route which gave the proper head-room was carefully selected, and, after traversing portions of several different railways, the special train which carried this one load finally reached Philadelphia. To place the girder on the masonry, the cars, with their load, were run directly under two cross girders which were placed on framed towers, as shown in Fig. 4. These two cross girders were subsequently used in the bridge. On these two cross girders and vertically over the center of gravity of the main girder were placed nine steel "I" beams, to

which the lines for lifting were attached. The main girder was unsymmetrical, and its center of gravity, the point at which the lines were attached, was computed. The pulling lines were run to two locomotives, and in ten minutes time the girder was raised onto the abutments.

The transportation and erection of this girder have been described somewhat in detail not only because it is one of the longest plate girders ever erected, but also to emphasize the importance of carefully studying the loading and transportation of these heavy pieces, and to bring out a method of erection of which I have not yet spoken, namely, the use of overhead bents of false-work. In

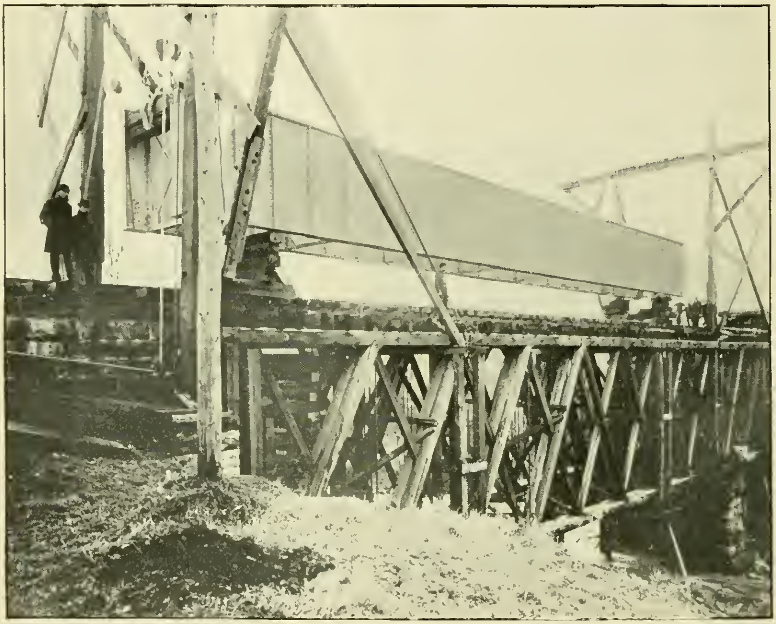

Fig. 5. Sunbury Bridge, C. A. and C. Ry. Youngstown Bridge Co.

this case two trestle bents were used, one on each side of the railroad tracks. Resting on these frames were two girders, which supported the load.

In February, 1896, on the Cleveland, Akron and Columbus Railway an old deck Howe truss bridge was replaced by a deck plate girder in the following manner: the steel girders were connected together in the shop and sent out ready to be placed on the supports. As shown in Fig. 5, the cars carrying the new span were run out onto the old bridge. A gallows frame was erected over each support in such a way that the girders could be sus-

pended from the cross beams of the frames. While the girders were thus suspended the cars were removed from the old bridge, the floor system and the top lateral system were taken out and the girders lowered onto the supports. The wooden trusses were then removed and the new track laid. These girders were 91 feet in length, and the time required for the erection was about seven hours. These frames are very useful in the erection of riveted trusses and long plate girders.

Another very common method to which reference will be briefly made is that of running the girders out on the false-work and then lowering them alongside the latter till they rest on the

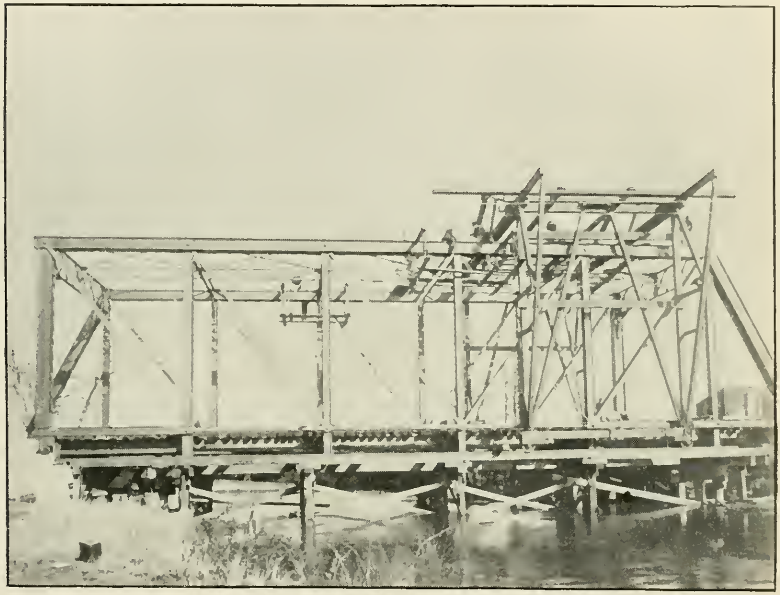

FIG. 6. MILLBURY BRIDGE DURING ERECTION.

abutments. The false-work is then removed and the girders slid laterally into position.

The girders of the Harvard Bridge, in Boston, were loaded on scows and floated out into position. They were then placed upon the piers with the aid of the tide and arrangements for increasing or diminishing the draught of the scows. This method will be mentioned later in connection with the erection of trusses.

Let us now consider the erection of simple trusses, that is, trusses which are supported only at the ends. After describing the false-work, the traveller, and the usual method of erection, some extremely interesting and ingenious solutions of problems in bridge erection will be presented.

During the early stages of iron bridge construction in this country the false-work for deck and through spans not only extended to the elevation of the lower chord, but was continued upward to the top chord. The truss members were handled from this upper false-work. At the present time, for deck bridges, the same general method is sometimes used for the false-work, but the truss members are handled by means of a movable tower which runs on a track supported by the false-work. This movable tower is called a traveller. In *nearly all* cases for the erection of *through* and *generally* for the erection of *deck* bridges the top of the false-work is placed a little below the elevation of the bottom chords of the trusses. Let us now consider the false-work used for bridges which are not very high above the bottom of the stream, and, first, where there is no traffic for which to provide. For single track structures this false-work consists of trestle bents of one, two, three or four legs each. These bents are placed about 20 feet apart, and are usually placed longitudinally and transversely. Each bent is capped by a timber which, of course, lies in a direction perpendicular to the length of the structure. On the caps are placed several lines of rough stringers, on which is a rough flooring. Fig. 6 represents this simple form of false-work, and on this temporary structure runs the movable tower or traveller. The floor just mentioned is usually about one foot below the lowest point of the steel work to be erected. The reason for this we shall see later. The trestle bents shown in this cut are made of piles, in which case they are either driven in position, piece by piece, or, each bent is framed together on shore and floated out into position and upended. This false-work may be used for deck or through bridges where there is no traffic; but when trains are continually passing over the line provision must be made to sustain the tracks while the old bridge is being removed and the new one erected. If the old structure is a through bridge, then the false-work as just described could be used, care being taken to place stringers underneath the old track to give proper support. If the old structure is a deck span the false-work is generally carried very nearly to the top of the structure, so that the old track may be supported during the renewal.

The legs of these trestle bents rest directly on the bottom if this is of rock or other compact material. When the bottom is soft these legs should rest on a sill to distribute the pressure. Frequently piles are necessary to carry the loads down through this soft material to the harder stratum underneath. Great care should be taken in arranging the false-work so as to prevent the

scouring out of the bottom, for if this happens to a great extent there is danger of precipitating the steel, traveller and false-work into the river.

Fig. 7 illustrates the erection of a long span curved chord bridge, and shows that for spans at a great elevation above the water two, three or even more stories must be used in the false-work. For such cases, in order to offer as little resistance as possible to the current and to the passage of drift or ice, it is better to build up the false-work not in single bents as shown, but in what may be called towers. These towers are 10 or 15 feet long in the direction of the length of the bridge. The space between them varies, and is frequently as much as 50 feet. When this distance

FIG. 7. OHIO BRIDGE AT CINCINNATI.

is not over 25 feet trussed stringers may be used to span the opening between the towers, but where it exceeds this distance Howe trusses should be used. Fig. 8 illustrates an example of this construction.

Let us now pass to the traveller, which runs back and forth on rails laid on the stringers of the false-work and spaced sufficiently far apart to enable the traveller to span the steel trusses. Travellers are usually made of wood and consist of two, three, or four bents braced together. At the foot of the posts are either single wheels or trucks, which run on the rails. The members comprising each bent are bolted together lying on the false-work. Each bent is then raised into a vertical position and connected to the

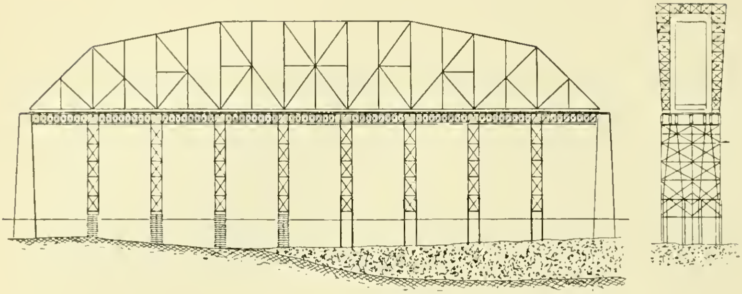

FIG. 8.*

others by the bracing. On top of these bents and in direction of the center line of the bridge, several lines of stringers are placed approximately over the center lines of the trusses. If the structure is not very high and the weights to be raised are comparatively light, a "crab" is usually placed on each corner of the upper deck of the traveller. The hoisting lines are attached to these "crabs,"

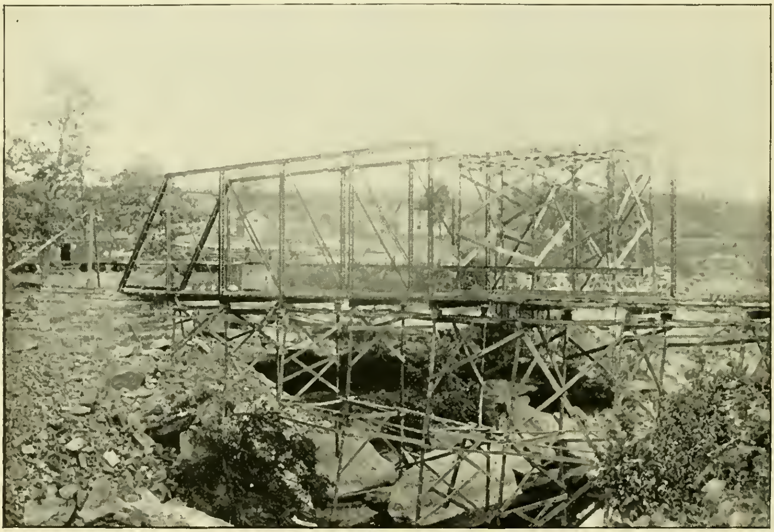

FIG. 9.

which are manipulated by man power. Sometimes they are placed on the false-work instead of on the traveller. Fig. 9 shows the simplest form of traveller.

Fig. 10 illustrates a traveller such as is used in erecting the longest curve chord trusses of the American type. For high bridges, where the distance through which the pieces must be

*From "The Strains in Framed Structures." Dubois.

raised is great, or where the weight is too heavy for man power, hoisting engines are used. These are usually placed at the ends of the span and the hoist lines run to the blocks at the bases of the traveller, and thence up to sheaves attached to the stringers on top. In Fig. 10 the hoisting engine is carried by the traveller. On the lower level may be seen one of the two boilers and two of the four drums for winding the hoist lines, and above may be seen the transverse beams resting on the longitudinal stringers. The transverse beams support the pulley blocks or sheaves. Such travellers as this constitute a very important part of the cost of construction. In the side elevation it will be seen that there are four bents, but,

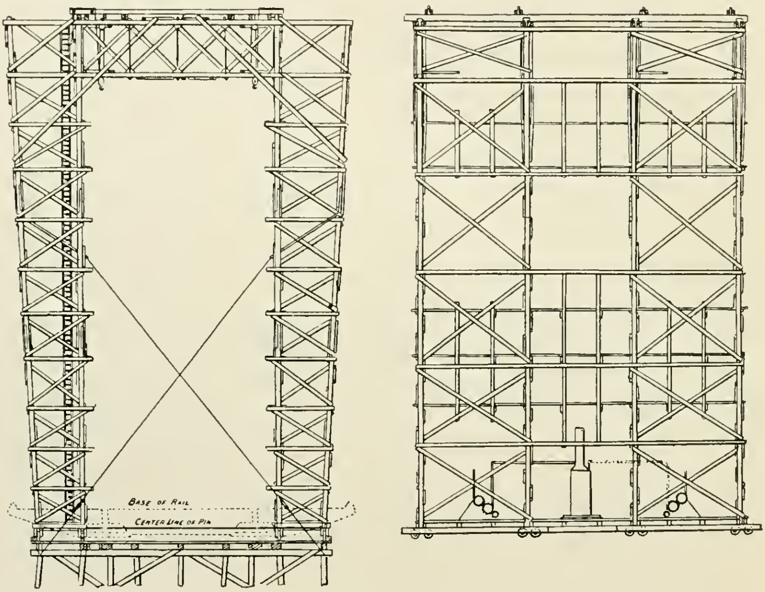

Fig. 10.*

as before stated, three or two are sometimes used. Instead of three bents it is probably cheaper to use only two, and instead of the middle bent use two inclined posts on each side. The description of these travellers alone would make a very long paper, but let us now pass to the erection of the steel work. With the aid of Fig. 9, I shall describe the assembling of the members of a small truss and merely state that the method employed for the long spans is practically the same as here outlined.

The center lines of the trusses and the panel points are first marked out on the false-work by the engineer. At these points is

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*From "The Strains in Framed Structures." Dubois.

placed blocking, upon which the lowest part of the steel work rests. A few moments ago it was seen that the false-work is carried up to within a foot or so of the lowest steel work. It is now apparent why this is done. This blocking placed upon the false-work and under the trusses at the panel points must be sufficient to give the trusses an increased camber, so that the distance between diagonal panel points is lessened. This enables an adjustment of the members so that the pins are easily driven. After this blocking has been placed in position the lower chord bars, washers, etc., are distributed in their proper places. The traveller is usually then run out to the center panel, where the top chord section is raised above its final position and lashed to the top of the traveller. By lashing this section in this way the "crabs" are free to raise the two vertical posts into position. The bottom ends of these posts, together with the lower chord bars, diagonals, etc., are then assembled and the pins driven. The posts are held vertically while the upper ends of the diagonals are raised into position. The top chord section, which has been suspended from the traveller, is then lowered and the top pins driven. In this way the center panels of the two trusses are erected simultaneously, and are then connected by the laterals. In connecting up this center panel care must be taken to have the trusses as near parallel as possible, and also to have the panel points of one truss exactly opposite those of the other. After the central panel has been finished the traveller is moved one panel length towards the fixed end of the bridge. In erecting this panel the procedure is practically the same as for the center. After the traveller has thus worked its way to the fixed end it returns to the center panel and erects that portion of the structure from this panel to the roller end. The blocking is then removed and the truss becomes self-supporting. The rivets connecting the floor system, etc., are then driven and the steel work is finished.

Although it is not *necessary* to begin the erection at the center of the span, it is better to do so, because here there are diagonals in both directions, bracing the panel thoroughly. The erection sometimes begins at the fixed and continues to the expansion end. The steel is generally raised directly into position from the cars, which are run out onto the false-work. The method here outlined is the usual one for pin-connected bridges. For riveted trusses the members are completely assembled and connected by means of bolts, which, after the trusses have been given the proper camber, are replaced by rivets.

Let us now turn our attention to some examples of erection,

which, on account of the extraordinary methods used, are very interesting.

Fig. 11 shows how an ordinary fixed span over the Columbia river was erected as a cantilever by building out from either end. The structure, as finally completed, consists of a 215-foot deck span, which extends from the mainland on the east over a side channel to a fixed tower on a small rocky island. The view is taken from the south, hence the east is on the right side of the illustration. The main channel is spanned by an ordinary curved chord bridge 416 feet long, extending from the fixed tower on the island to a rocker tower which is supported on the west bank of

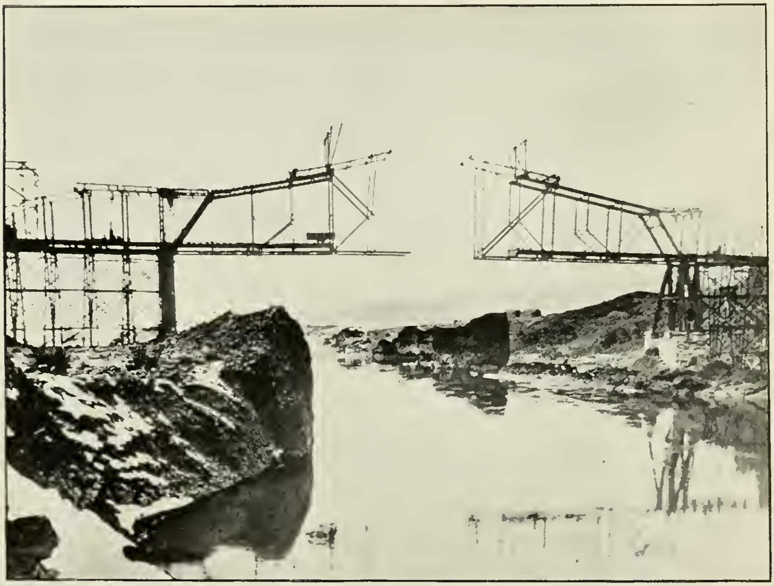


Fig. 11. Columbia River Bridge. Edge Moor Bridge Works.

the stream. This bank rises vertically from the water, and the tower is set within a few feet of the edge. The projecting rock seen on the left is in the foreground, hence the view of the rocker tower is somewhat misleading. From this rocker tower there is a trestle carrying a sharp curve running westward to the left. Upon first thought the question might be asked, why not use a cantilever bridge? This was impracticable on account of the curve just mentioned, which is necessary to avoid the rocky precipice on the extreme left of the bridge. This precipice is not shown in the illustration.

The depth of the water in the main channel was 130 feet at

the time of the erection, and on account of this depth and the rapidity of the current it was practically impossible to use false-work for the erection of the long span. As shown in the view, false-work was constructed for the short span over the east channel and for the approach on the west of the long span. At each end of the channel span one-half of the 215-foot deck span was then temporarily erected upside down on the false-work. The main channel trusses had been designed with stiff bottom chords, so that it was erected piece by piece as a cantilever. Each portion of the channel span was connected to the portions of the inverted deck span by means of eye-bars and struts made especially for the purpose. The cars carrying the material were then run out on the

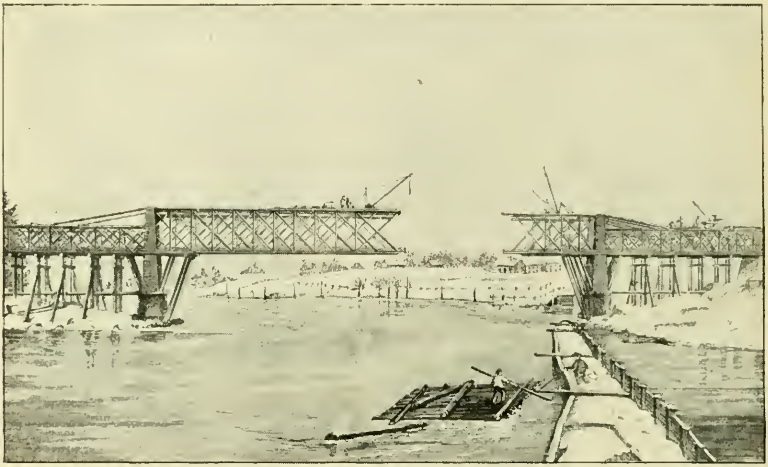


FIG. 12. BRIDGE OVER RIVER DAL IN SWEDEN.*

main track underneath the travellers, which may be seen on the top of the top chord near the opening. These travellers, one on each half of the bridge, thus placed into position piece by piece, till the two overhanging arms met at the center. As the weight of the projecting arms increased, steel rails were added to the outside ends of the anchor arms. A large mass of these steel rails may be seen on the extreme left. On the left may also be seen the traveller, which was used in handling the material of the inverted deck span. The projecting arms are now meeting at the center, but as yet nothing has been said about driving the last pins. Unless the members meet at the center, the last pins could not be inserted into the holes provided for them. It is impossible to start the erection

*"Girder Making and Bridge Building." Hutchinson.

and determine the deflection so that the final pin may be driven without adjusting the members. This adjustment was made in this bridge by means of three wedges for each truss, one in the line of the bottom chord to the left of the rocker tower and one at the top of each of the vertical posts over the towers. By these wedges the center of the span could be raised or lowered, and the distance along the bottom chord between end-pins could be increased or diminished. By means of these wedges the holes of the various members meeting at the center of the span were brought

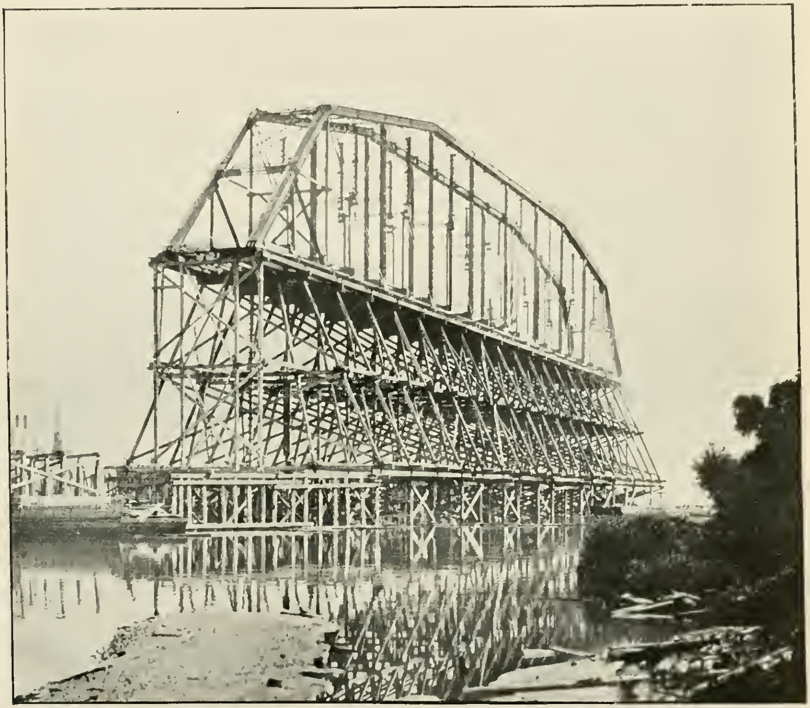


FIG. 13. OHIO CONNECTING RAILWAY BRIDGE NEAR PITTSBURG. KEYSTONE BRIDGE COMPANY.

into line, the pins were inserted and the trusses became self-supporting. The two portions of the deck span were then taken down and erected in proper position.

How the same general method as that just described was applied to the erection of a bridge over the river Dal, in Sweden, is shown in Fig. 12. This structure was built about 1874. At either pier may be seen the temporary supporting ties which were attached to the projecting portions and to the adjacent spans during erection.

Another interesting example of erection without constructing false-work in the river under the final location of the bridge is illustrated by the manner in which the 523-foot channel span of the Ohio Connecting Railway Bridge, near Pittsburg, was floated out into position and lowered onto the piers. To avoid obstructing the great volume of traffic at this point and the sudden floods to which the Ohio river is subject, it was concluded to erect the long channel span on false-work in the shallow water near the shore about 500 feet below the bridge. Fig. 13 shows the completed

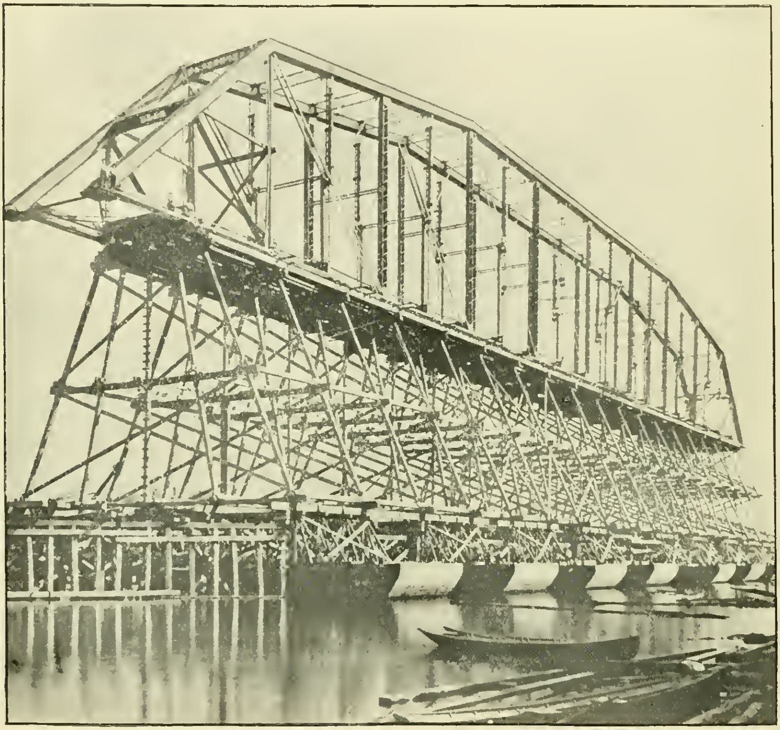


FIG. 14. OHIO CONNECTING RAILWAY BRIDGE.

span as it rested on the false-work parallel with the shore and at right angles to the center line of the bridge. It will be observed that the false-work rests on several pile bents, spaced sufficiently far apart to admit barges, as shown in Fig. 14. Each of the nine barges was partially filled with water by opening valves placed in the bottom. After placing these underneath the false-work and bracing the entire mass thoroughly, the water was pumped out of the vessels, which then rose, carrying the false-work and span vertically till the former was clear of the piles. This line of barges,

with its burden, was then revolved through 90° and towed upstream into position till the ends of the trusses were just over the piers. The valves in the bottoms of the barges were then opened, and as the water flowed in the span settled down upon the piers provided for it. The barges and false-work were then removed. This was a wonderful feat of engineering, especially when we consider that the steel and false-work together weighed 1800 tons and that the topmost part of the trusses was 150 feet above the water. The barges which are seen in Fig. 15 are not those which carried the span, but were placed on the upstream side for protection.

Several other large bridges have been erected in this manner.

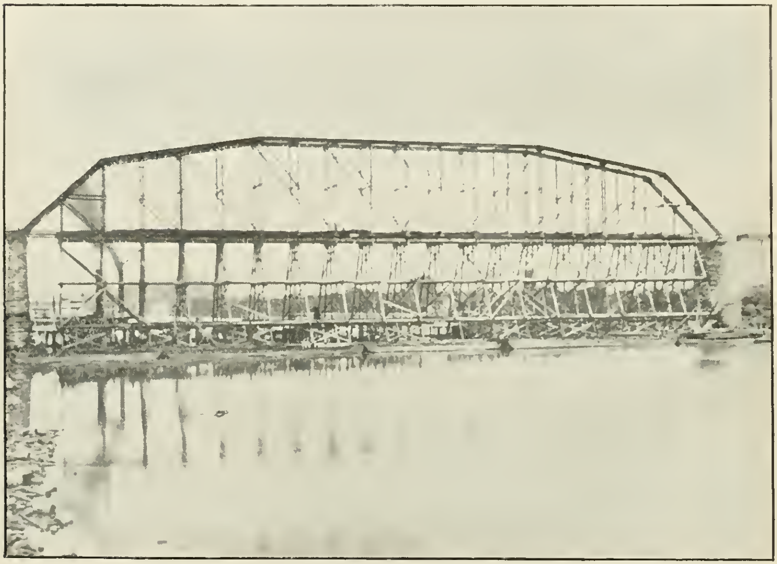


Fig. 15. Ohio Connecting Railway Bridge.

The method by which the trusses of the Boylston street bridge over the Boston and Albany Railroad, in Boston, were placed upon the abutments is illustrated in Fig. 16, which shows a portion of the staging upon which one of the trusses was erected alongside of and parallel to the railroad tracks. The more distant end was supported on iron rollers resting on a wooden tower, which in turn was placed upon wooden rollers. The nearer end was supported on a hydraulic jack on the abutment. At a convenient time between the passage of trains the truss was swung about the jack as a pivot, the tower moving upon the wooden rollers running on timber sills laid across the tracks. When the tower reached the abutment the end of the truss was brought to the proper elevation

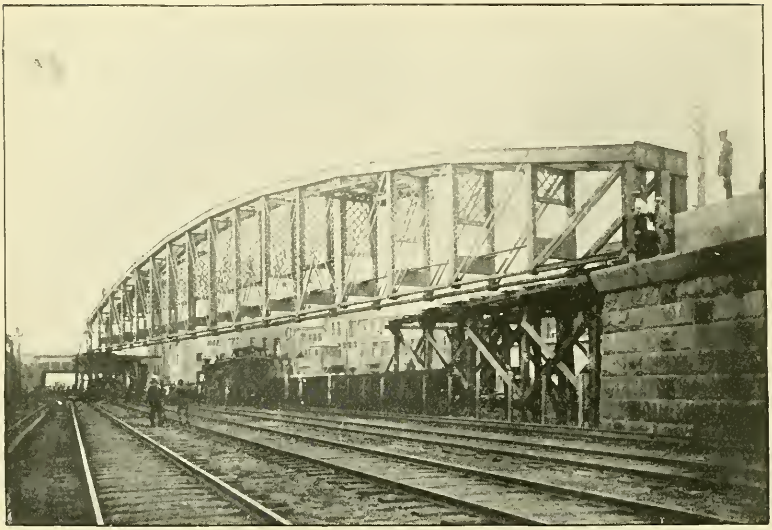


Fig. 16. Boylston Street, Boston.

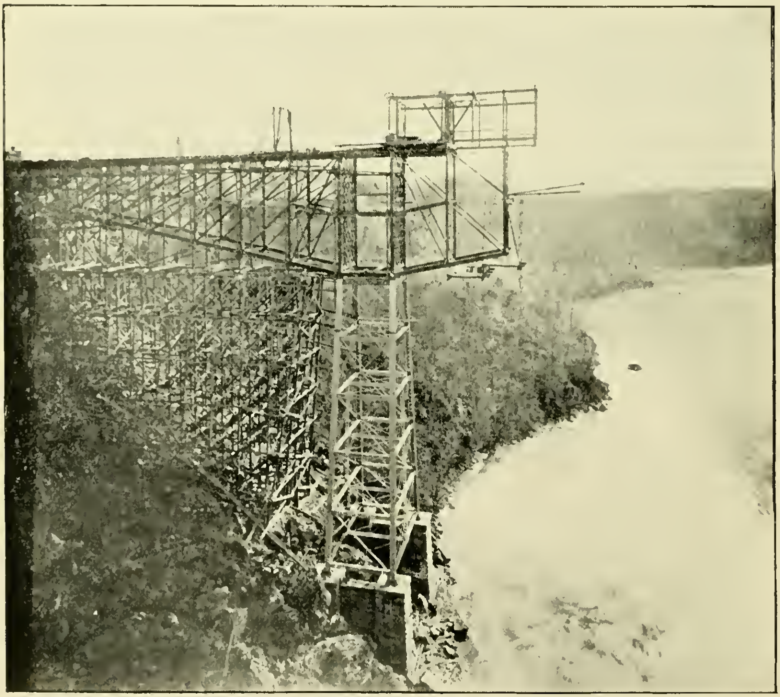


Fig. 17. Cantilever at Niagara.

by means of jacks, and the truss was rolled from the tower to the abutment on the iron rollers. Fig. 16 shows one of the trusses while the tower was being moved across the tracks.

Although the principle of the cantilever was known many centuries ago, it remained for the engineers of modern times to apply it to the construction and erection of long spans across deep and dangerous streams. As shown in Fig. 17, the cantilever is especially adapted to locations where false-work cannot be employed. The illustration is taken from the bridge at Niagara Falls, and shows a typical pin-connected, deck cantilever. Each side consists of an anchor arm extending from the abutment to the tower and a cantilever arm projecting from the tower over the river. At the outer ends of these cantilever arms is supported the suspended span, which is a simple truss.

For the erection of such a structure false-work, similar to that already described, is constructed from the abutment to the tower. Beginning at the shore end, the anchor arm is erected upon this false-work. The traveller, somewhat different from that already described, is arranged to move on top of, and to overhang the finished portion. The projecting arm and the suspended span are erected piece by piece from the overhanging traveller, which receives the material either from cars run out on the structure, or, as in the case of the Poughkeepsie Bridge, from boats underneath. Platforms suspended from the traveller enable the workmen to handle the parts along the lower chord. As the overhanging arm progresses there is a tendency for the anchor arm to rise from the abutment. This is prevented by the weight of the latter arm and by anchoring the end to girders built in the masonry. The projecting portions are carried out each side till they meet in the center. At this point, unless provision has been made for the final adjustment to facilitate the insertion of the last pins, it is almost impossible to complete the erection. As before suggested, the pedestals cannot be so correctly set at the abutments and towers that there will be no adjustment necessary at the center. Wedges for final adjustment are usually provided in the bottom and top chords at the panels between the projecting arms and the suspended span. By means of the wedge in the top chord the outer end of the projecting arm may be elevated or depressed at will, and with the aid of the wedge in the bottom chord the distance between end-pins in this chord may be increased or diminished. It is obvious with such provision for final adjustment the cantilever may be easily erected.

The erection of the Red Rock cantilever bridge over the Colorado River is shown in Fig. 18. The method of erection for a

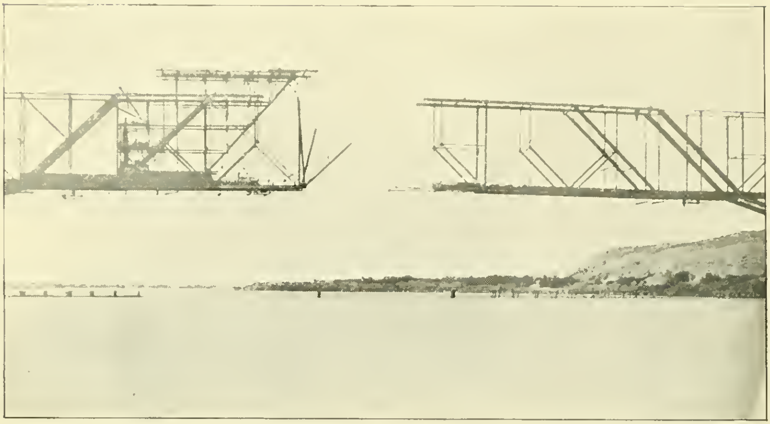


Fig. 18. Red Rock Cantilever over Colorado River. Phoenix Bridge Company.

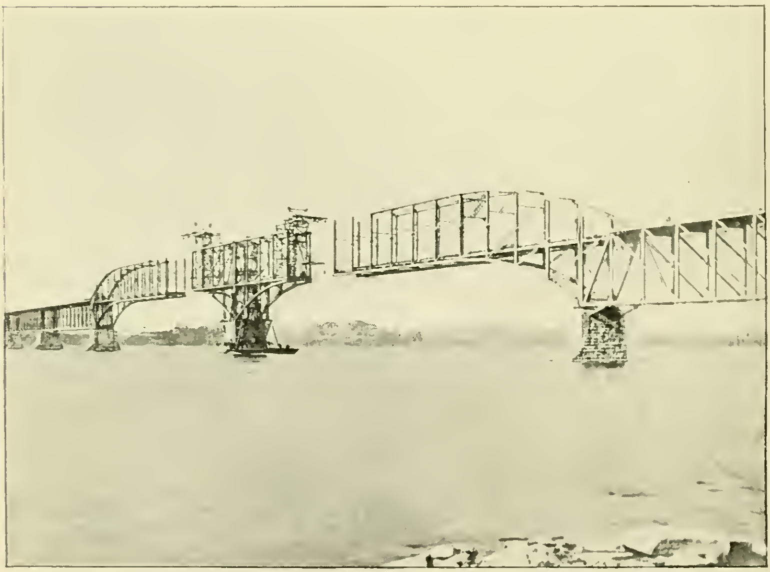


Fig. 19. Cantilever at Lachine, Canada.

through cantilever such as this is very similar to that of the Niagara Bridge already described. The traveller in this case runs inside the steel work, while in erecting a deck cantilever it runs on top.

Drawbridges are usually erected on the fender pier, that is, open, but sometimes they are constructed as cantilevers by building out simultaneously on each side of the pivot pier. This method as applied to the erection of a central span of the *cantilever* bridge at Lachine, Canada, is shown in Fig. 19.

The usual method of erecting arched bridges is shown in Fig. 20, which illustrates the Washington Bridge over the Harlem river in New York City. This structure consists of two 510-foot

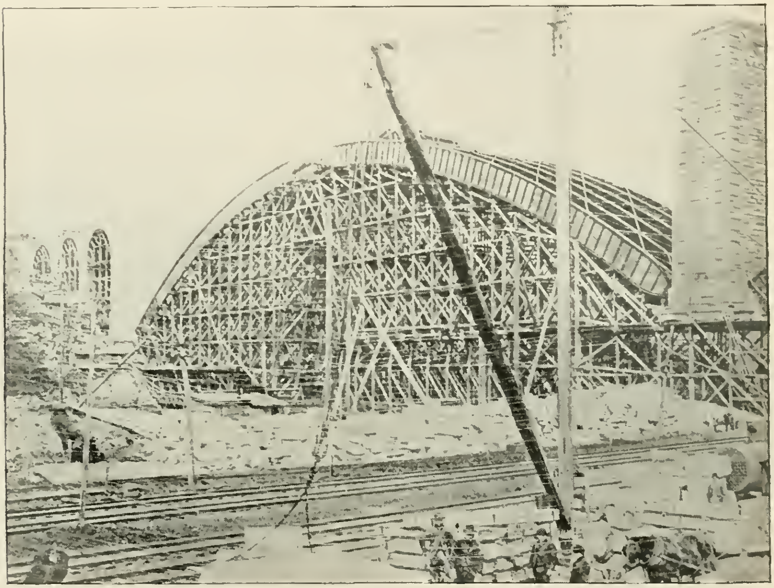


FIG. 20. WASHINGTON BRIDGE OVER THE HARLEM RIVER.

spans. Each span is composed of six curved girders, sent to the bridge site in sections 12 or 15 feet long and 8 feet deep. By means of derricks these sections were elevated to cars upon a platform, from which they were delivered to the traveller. This traveller ran on top of the girders and was adjustable to fit the varying inclination.

Figs. 21 and 22 illustrate the famous Ead's Bridge in Saint Louis. Each arched rib of this structure consists of two tubes connected in a vertical plane. The erection of these ribs was accomplished without the aid of false-work by beginning at the piers and building out piece by piece. Each portion of the arch, as

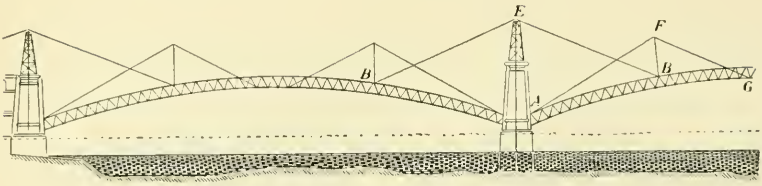


Fig. 21. Erection of Ead's Bridge.*

it projected outward, was supported by cables carried up over a wooden tower placed upon the adjacent pier or abutment. The method is illustrated diagrammatically by Fig. 21, showing a portion of the arch supported by the cables. Fig. 22 is reproduced

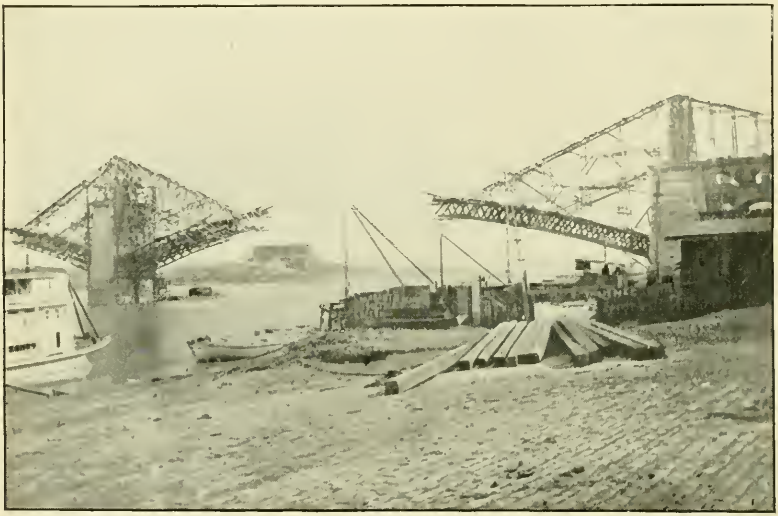


Fig. 22. Ead's Bridge at St. Louis.

from a photograph taken at the time of erection. Here again the problem of closing the span at the center arose, and, as no provision had been made for the final adjustment, great difficulty was experienced in connecting the two projecting arms of the first span. It was found that the distance between the two projecting portions was too short to admit the section of the tubes intended for the opening. The arches were then cooled by the application of ice, but the intervening space could not be increased sufficiently to admit the tubes. After several unsuccessful attempts to close the arch by this means, the problem was solved by using adjustable

*From "The St. Louis Bridge." Woodward.

sections of tubing. The application of ice is generally supposed to have been successful, but in his valuable work on the Saint Louis Bridge, Professor Woodward shows that the arches were not closed by this method. In this connection I should like to say that the statement is frequently made that the tubes of the Victoria Bridge, at Montreal, were erected upon false-work constructed on the ice. The examination of the report of the engineer for the contractors shows no evidence that such was the case. Judging from this authority, it seems that the false-work was supported on the bottom of the river, and not on the ice.

The arched span of the Garabit Viaduct in France, shown in Fig. 23, affords an example of erection very similar to that employed on the Ead's Bridge. The viaduct consists of six spans,

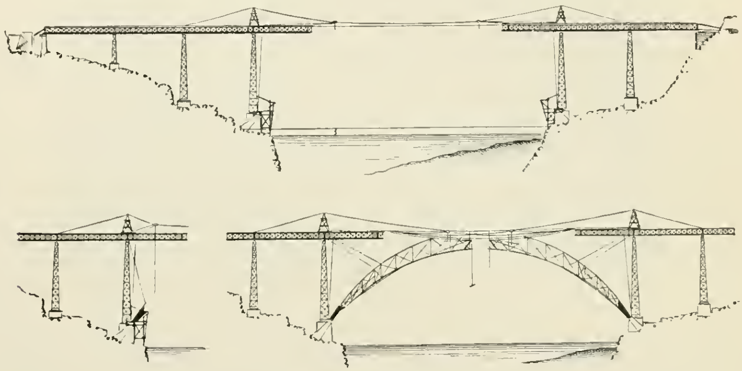


Fig. 23. Garabit Viaduct in France.*

one of which, the river span, is an arch of an approximate length of 541 feet. The mean rise is about 213 feet. The upper portion of Fig. 23 represents the appearance of the structure at the beginning of the erection of the river span. The towers had been completed and the trusses pushed out from the banks till their outer ends protruded over the opening, as shown. The arch panels nearest the piers were next erected on false-work and then supported with cables from the overhanging trusses above. This is shown in the upper figure and in the lower one on the left. By means of the overhead cables and sheers which rested on the completed portion of the arch, the material was raised, piece by piece, from cars running on a temporary trestle beneath and placed in position. As work on the projecting portions of the arch progressed more cables were added to give the necessary support. In this manner the span was finally closed, the measurements having

*From "Viaduc de Garabit." Boyer.

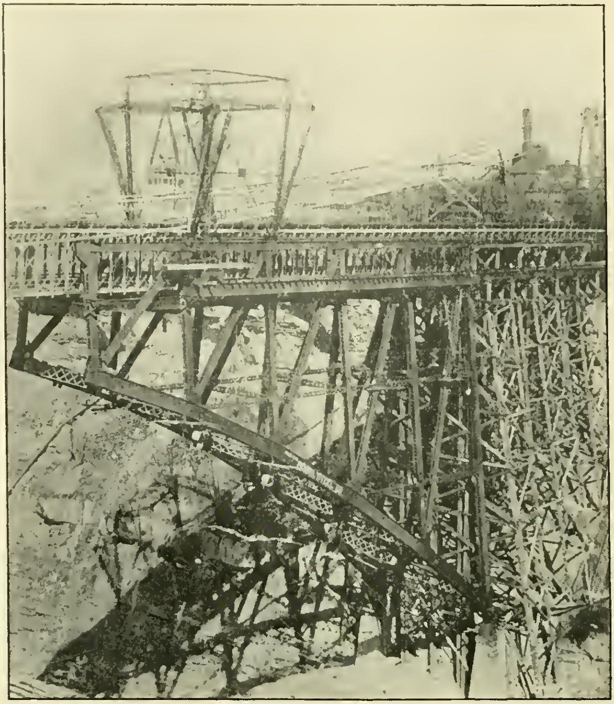


FIG. 24. NIAGARA ARCH. PENNSYLVANIA STEEL COMPANY.

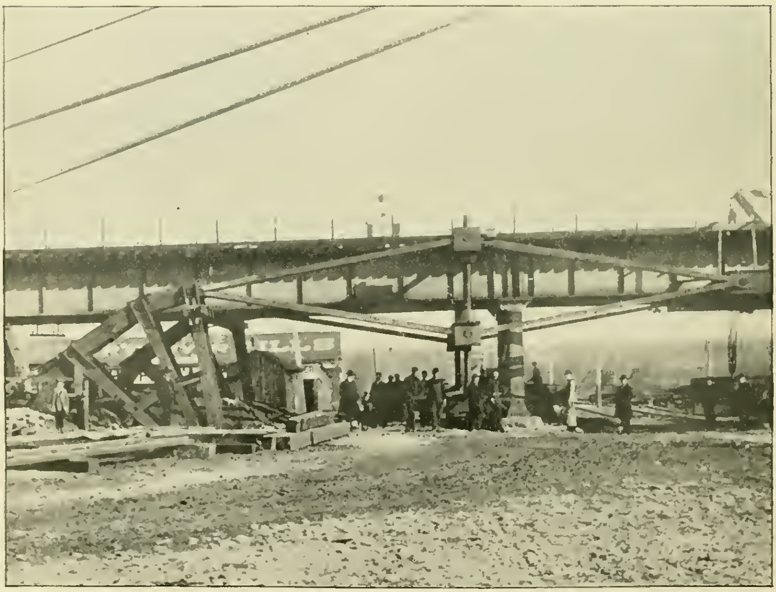


FIG. 25. TOGGLE OF NIAGARA ARCH.

been so accurately made that no adjustments were necessary to place the central members in their proper positions.

The new two-hinged arch bridge over the gorge at Niagara Falls, illustrated in Fig. 24, was erected as a cantilever by building out simultaneously from each side. Each projecting portion was supported at the skew-back, and at the top were attached eye-bars extending back horizontally to an anchorage in the rock. The arches could thus be supported without false-work during erection. In order to facilitate the closing of the arches at the center, a large

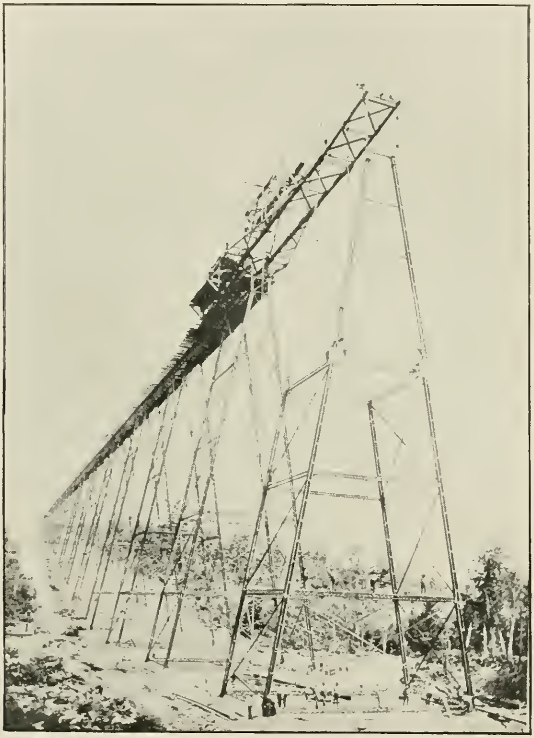


FIG. 26. PANTHER CREEK VIADUCT.

toggle-joint was inserted in the line of the horizontal anchorage just mentioned. By means of a vertical screw in this toggle the position of the outer end of the projecting arm could be varied. This joint is shown in Fig. 25.

The last type of structure to which I shall call your attention is the viaduct. These are erected by gin-poles, derricks, etc., or by a traveller which rests upon the finished portion and overhangs a sufficient distance to erect the next tower adjacent to the finished

portion. After the tower is complete, the girders are placed across the opening from the finished portion, upon which the traveller is supported, to the tower ahead. The traveller is then moved forward and another tower is erected in the same manner as the preceding. Fig. 26 represents the erection of the Panther Creek Viaduct in Pennsylvania. The photograph was taken just as a section of the tower was being placed in position.

DISCUSSION.

Mr. J. Parker Snow.—The author speaks of the difficulty of erection that occurs when proper care is not taken by the designer in keeping rivets out of the way of the parts which must be assembled in the field. Another trouble with rivets often occurs when, from careless designing, they are placed where they cannot be easily driven after the structure is erected.

Trouble often arises also where riveted chord sections are so designed that they have to be telescoped endwise in order to get them in place. It is often thought by designers that all rivets possible should be machine-driven at the shop, and they make the mistake of shop-driving one end of the splice plates, leaving the sections to be telescoped in the field in order to get the whole in place. If these are so designed that the chord can be driven together sidewise, it is sometimes not difficult to do it, but if it must be forced together endwise the difficulty is considerable. A maul or battering ram will have considerable effect in driving a chord sidewise, but not much if it is attempted to drive it endwise. A little care on the part of the designer will make these joints so that they can be put together quite easily, but it is better to leave more rivets to be driven in the field than seems absolutely necessary rather than to drive too many in the shop, thinking to thereby save field work.

Trouble and delay occur also when stringers of a railroad bridge are headed into the floor beams where there is no shelf angle put under the ends of the stringers to support them before the rivets and bolts are inserted. The ordinary method of putting up a railroad bridge, as was not perhaps quite clearly brought out by the paper, is to put up the trusses first and then take out the floor of the false-work and put in the new floor of the bridge. The passage of trains is but little hindrance in erecting the trusses, but in putting in the new floor a large amount of extra work is involved if it is necessary to restore the track to allow a train to pass before the span is completed. Hence this part of the work is generally done at night, or on Sunday, when trains are few. Even then the

time is short for all the work to be done, and the floor should be so designed as to go together with the least possible trouble. Where there is no shelf angle under the ends of the stringers, they must be hoisted exactly right, so that the holes will match, in order to insert a bolt or pin. This is a very difficult thing to do with a steam purchase, because the stringer binds between the floor beams, of course, and when the strain is sufficient to start it it will come too far, whereas if there is a shelf angle for it to rest on it need only be landed on that shelf, when the hitch can be cast off and made ready for the next hoist. If there is no shelf angle, after you have erected one panel and attempt to put in the stringers of the next panel, all the bolts must be taken out before you can put in these stringers, and you have to support the last stringer put in as best you can until you get the second panel in place so that both can be finally bolted up. Time is precious when erecting floors, and these shelf angles accelerate the work enough to pay many times for their cost. A double-track floor can be erected with them as rapidly as a single-track floor without them.

The speaker stated that one advantage of pin-connected bridges was that trains could run over them before any riveting was done. It is almost universally necessary to do this in the case of riveted bridges also. I generally prescribed in such cases that about one-half of the holes shall be filled with bolts. This seems to be sufficient to carry the loads without distress to the bolts and other connections. It is generally quite difficult to get a foreman to put in as many as that. There is no trouble, with proper precautions, in running over a bridge of any kind before the rivets are driven.

The paper did not mention the use of derrick cars to any great extent in the ordinary erection of a truss bridge, but it is possible to put up bridges, and it is frequently done, with self-propelling derrick cars alone, without the use of a traveller. In erecting trusses, however, I think the traveller is, on the whole, preferable, but the difference is not great. It is in every way possible and very convenient to put them up with the derrick cars, and in changing the floor I think the cars have the advantage. They take up a part of the old floor, carry it ashore, and land it where desired, and carry the new iron in and put it in place, and when it comes to removing the false-work, the derrick cars are of great advantage. The traveller cannot be used for this, of course, because it must be taken down before the false-work is removed. This method of erection is used largely by only one concern that I know of, namely, the Boston Bridge Works. Of course, if a bridge is to be

erected several hundred miles from headquarters, the transportation of derrick cars is an objectionable feature, but where it is not far away from the home shop the freight on them does not amount to much.

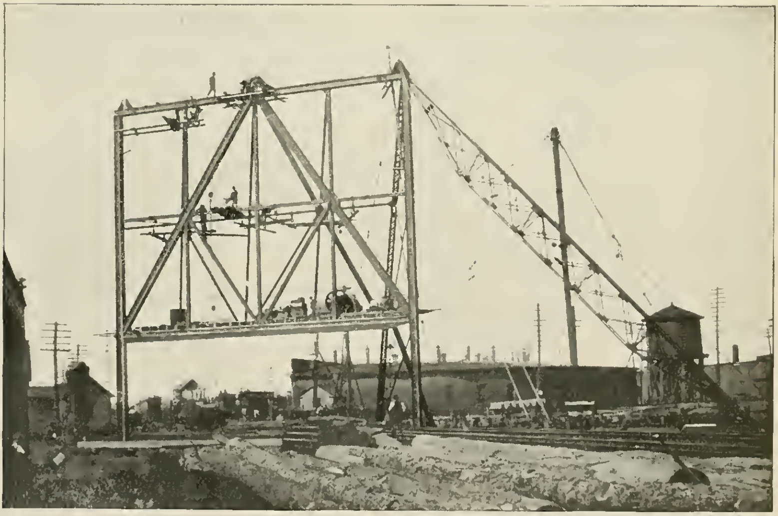
It is not so difficult a matter to erect a bridge and maintain railroad traffic over it while it is being erected as many seem to imagine. In the case of a highway bridge, however, the travel must be shut off. In some cases, but very seldom, it is advisable to throw the traffic onto a temporary trestle running around the site of the bridge. This occurs in the building of some stone arches, and sometimes in building piers in a wide river. Ordinarily it is not advisable on the score of economy. It is more often advisable to build the bridge at one side of its final position and slide it into place when completed, but this is seldom necessary. In erecting drawbridges, either the trains must be discontinued or navigation closed until the bridge is practically completed.

One point that was not touched on in the paper, but which is frequently mentioned in specifications, is the use of drift-pins in erection. Specifications often require that "no drift-pins shall be used." Now, that is absurd, for it is next to impossible to erect a bridge without the use of drift-pins, and, if properly used, they do no harm. In fact, it is hardly possible to damage a fair hole by drifting it. The specifications under which I work say that "no drifting to enlarge unfair holes will be allowed," and that, I think, is about as far as an engineer has any business to go in saying what the contractor shall use. If the structure is not injured the contractor ought not to be limited as to the tools that he may use.

It is a question whether it is best for the railroad companies to erect their bridges or to let the bridge companies do that part of the work. Some railroad companies do all of the erecting and others do none. It seems to me advisable to modify both of these customs, and to have the railroad company do such erecting as it can with the tools it has, and, when the work gets beyond the capacity of those tools, to allow the contractor, who is specially fitted up for it, to do the work. In the case of deck plate girders and the like, such as described in the paper, a railroad which is fitted up as the Boston and Maine is, for instance, can do the work of erection much better than a contractor can.

A car pile-driver is an excellent thing for handling one end of plate girders. Two of them cannot very well be used, but the driver can be used at one end, running it up to the end of the bridge and hoisting that end with it, and then by means of a gallows frame at the other end, or by means of a timber underneath the bridge

Miller's River Drawbridge During Construction, B. and M. R. R.



Miller's River Drawbridge During Construction, B. and M. R. R.

projecting beyond the sides of the car to allow the use of jacks, that end can be raised, the car withdrawn and the bridge lowered. It is ordinarily much quicker to do this by means of a gallows frame than by jacks, because with the gallows frame the hitch is made, and when the car and false-work are cleared away it is a matter of but a few minutes to lower the bridge to its place. Heavy plate girders can be handled in this way very readily up to 75 feet span, at least.

Mention was made of erecting plate girders singly, one at a time. Unless the girders are tremendously large, I think deck girders had always better have the floor or bracing riveted in. They can be handled and shipped in this way with much less risk of injury than if single. It is also more economical, because there will then be no riveting in the field, and the erecting is all done in one piece.

Mr. B. W. Guppy.—In erecting the trusses of the Boston and Maine Railroad drawbridge over Millers river, a tool was used not mentioned in Mr. McKibben's paper, namely, a pile-driver, in this special case mounted on a scow.

The bridge was originally a double-track wooden jackknife draw, and was rebuilt, in connection with the building of the Northern Union Station at Boston, as a four-track iron jackknife draw.

The trusses were built under a separate contract from the gallows frame, and arrived at the bridge site riveted up complete, the longest truss being over 90 feet long. The erection of the trusses was done by the railroad company .

The trusses of the two additional tracks were first put in place. The loaded cars were run out onto the wharf along the river and the trusses picked up by the scow pile-driver, carried to the bridge site and lowered into place. Travel was then turned onto the new tracks, the pile-driver dismantled and passed under the bridge at low water, and then put in order again and used to remove old trusses, drive piles for foundation and put the other four trusses in place. These were erected by running the loaded cars onto the trusses previously erected, picking up trusses with the scow pile-driver and lowering them into place.

The gallows frame was erected by the contractor who built it. It is 70 feet high, spans four tracks, and has a width of 30 feet at the base.

It was designed and built in as few pieces as possible, and was erected by means of gin-poles. One was used at first, but when the flying strut was put in place it was necessary to make use of a

second. Erection was done during the winter, and arrangements were made with the coal companies up river to hasten or delay their vessels so that traffic by river would be delayed as little as possible. As it was, the draw was closed for about six weeks. There was no interruption to railroad travel.

Mr. Horace J. Howe.—In this connection I am reminded of the erection of the two island spans of the Chemung River Bridge of the Erie Railroad, at Elmira. The spans were made up of two pairs of plate girders, about 70 feet long, which were unloaded by means of two derrick cars on each side of the double track, blocking or cribbing having previously been prepared up to the level of the tracks. All parts were assembled and riveted up, and the whole was then slid over on greased rails by hydraulic jacks, the heavy traffic meantime being taken care of on the other track. Quite a number of persons were anxious to claim credit for the idea afterwards.

Mr. F. P. McKibben.—The method just described, that is, erecting the new bridge completely alongside of the old span and then shifting the two structures laterally till the new span occupied the position formerly held by the old, was used very effectively in replacing Bridge No. 69 on the Pennsylvania Railway, near Girard avenue, Philadelphia.

The time required for the removal of the old and the simultaneous substitution of the new span was 2 minutes and 30 seconds. The entire erection required about two months.

RAINFALL AND RUN-OFF IN RELATION TO SEWERAGE PROBLEMS.

By Walter C. Parmley, M.S., Member of the Civil Engineers' Club of Cleveland.

[Read before the Club, February 8, 1898.*]

The relationship existing between the rate of precipitation and the proportion of the rainfall which finds its way immediately into the sewer is one of great importance to the sewerage engineer. If the sewer that he constructs be of excessive size, the cost in excess of that warranted by the actual needs is money wasted. On the other hand, if the sewer he builds proves inadequate, not only must the engineer endure the righteous censure of the community, but the sewer may be ruptured and cellars become filled with water, thus inflicting immediate damage to property, or, what may be still worse, cause a general depreciation in the neighborhood impossible to estimate in money value.

The subject, therefore, has been given much study by engineers, and various formulas expressing this relationship have been proposed. None have proved entirely satisfactory, since, from the nature of the case, they must be empirical and subject to many elements of variation and uncertainty. The discussion naturally falls under two heads: first, the probable intensity of rainfall, and, second, the finding of a suitable mathematical expression of the laws governing the concentration of the water in the sewer.

RAINFALL.

Valuable data have been collected by Kuichling† regarding the intensity of rainfall, and by Professor Talbot,‡ who reduced to graphical form most of the data then available. The recent report of the Sewerage Commission of the city of Baltimore also contains additional information.

Most of the information on the subject gives intensities for rains of varying durations, but does not give a continuous record of the progress of each individual storm. In Figs. 1, 2 and 3 are shown graphically the record of all those rains, exceeding one inch

*Manuscript received March 7, 1898.—Secretary, Ass'n of Eng. Socs.

†Trans. Am. Soc. C. E., Vol. XX.

‡Technograph No. 6, of the Univ. of Ill., 1892-93, and abstracted in the *Eng. News*, July 21, 1892.

rainfall in one hour, occurring in the United States in 1896, which were recorded on Government automatic rain gauges. The data from which they are prepared are those given by the *Weather Review* and published in *Engineering News*, June 24, 1897, p. 387. Table I gives the intensity of precipitation for each five-minute period during the first hour, and is valuable as showing the fluctuations and behavior of storms during their passage. It is to be noted that only storms yielding at least one inch of rainfall in one hour or less are here recorded. Other storms of like or greater intensity occur which might tax the capacity of a sewer even more severely, but this record includes only those storms which not only were intense, but were unusually persistent in their nature.*

By casual observation, the following facts may be noted: In the five North Atlantic cities there were six storms yielding one inch of rainfall in an hour, or each city experienced at least one such storm. There were four storms yielding 0.75 inch in thirty minutes, or at the rate of 1.5 inches per hour; and there were two storms yielding 0.62 inch in fifteen minutes, or at the rate of 2.5 inches per hour.

In the nine South Atlantic and Gulf cities there were storms yielding the following intensities: In one hour, at the rate of 1 inch per hour, 27; thirty minutes, at the rate of 1.5 inches per hour, 19; for fifteen minutes, at the rate of 2.5 inches per hour, 5.

In the fifteen Central and North Central cities there were: For one hour, at the rate of 1 inch per hour, 27 storms; for thirty minutes, at the rate of 1.5 inches per hour, 23 storms; for fifteen minutes, at the rate of 2.5 inches per hour, 11 storms. Of this group of cities only Chicago, Cincinnati, Denver, Dodge City, Kan., and Nashville failed to have at least one storm at the rate of 2.5 inches per hour for fifteen minutes.

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*There occurred in Cleveland, for example, during the year, two rains which were more severe than some recorded; but, as neither yielded one inch of actual rainfall in one hour, they do not appear in the above table. That they were severe storms, the following rates, in inches per hour, for various intervals, will show: Storm of June 7, 1896: For 5 min., 3.60 in. per hr.; for 10 min., 2.70 in.; for 15 min., 2.40 in.; for 20 min., 2.10 in.; for 25 min., 1.92 in.; for 30 min., 1.70 in.; for 40 min., 1.42 in.; for one hour. 0.99 in.; for 2 hrs., 0.54 in. Storm of June 24, 1896: For 5 min., 1.80 in.; 10 min., 1.50 in.; 15 min., 1.40 in.; 20 min., 1.20 in.; 25 min. 1.08 in.; 30 min., 1.20 in.; 35 min., 1.11 in.; 40 min., 1.13 in.; 45 min., 1.07 in.; 50 min., 1.02 in.; 1 hr., 0.90 in.; 2 hrs, 0.55 in. The following rain occurred in Pittsburg, July 15, 1896, and was reported by the signal observer at the time, but which does not appear in the above records from the *Weather Review:* For 5 min., 0.35 in.; 10 min., 0.65 in.; 15 min., 0.90 in.; 20 min., 1.05 in.; 25 min., 1.35 in.; 30 min., 1.40 in.; 35 min., 1.40 in.; 50 min., 1.45 in.; 1 h., 1.46 in.

TABLE I.

Showing the Intensity of Precipitation in inches per hour for Each Five-Minute Period up to Fifty Minutes and for the Ten-Minute Period from Fifty Minutes to One Hour, for Rains Occurring in the United States during the Year 1896.

NORTH ATLANTIC CITIES. PERIODS IN MINUTES.

	0-5	5-10	0-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-60
Baltimore.											
1. July 21	2.52	1.68	1.32	1.44	.48	.24	.36	.36	1.56	1 44	1.38
2. Sept. 19	3.00	4.20	3.00	.84	.36	....	....	....	....	....	....
Nantucket, Mass											
3. July 6	1.44	1.44	1.56	.60	.48	.36	.72	.60	.48	1.32	2.40
New York.											
4. July 6	2.40	2.64	2.16	2.76	.72	.60	.60	.24	....	....	....
Portland, Me.											
5. Sept. 6	1.44*	1.44*	1.44*	1.44*	1.20	2.64	2.16	1 80	1 56	3.24	.30
Washington.											
6. Aug. 13	1.68	2.28	5.04	2 40	2.40	2 28	1.32	.84	.60	....	....

SOUTH ATLANTIC AND GULF CITIES.

	0-5	5-10	0-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-60
Galveston.											
1. March 15	1.20	2.40	.84	1.20	1.80	1.56	.84	.36	.36	.24	.60
2. July 11	3 60	1.80	1.44	.96	1.44	1.56	.96	.72	.72	.36	.60
Jacksonville, Fla											
3. March 11	1.68	.72	1.80	6.00	.60	1.32	....	....	....	....	....
4. June 4	.84	.84	3.96	5.40	4.56	3.24	.12	.24	1.32	.96	1.20
5. June 19	3.60	3.72	1.08	.84	.60	.36	.24	.24	1.32	1.80	....
6. Aug. 4	.48	2.64	2.16	3.00	1.44	1.20	1.56	.96	.36	.36	....
7. Aug. 26	.60*	.72*	1.08*	1.68*	1.92*	4.20	2 64	1.56	3 60	1.80	.90
Jupiter, Fla.											
8. Jan. 25	.36	.36	.48	.72	1.68	1.56	.96	1.80	4 80	3.60	1.20
9. July 10.	1.20	3.00	2.40	.48	.96	.96	1.80	2.40	....	....	....
10. Sept. 9	.84	2.04	3.24	2.64	1.80	.96	.60	1.08	.48	.36	....
Key West, Fla.											
11. Nov. 7	.60	.60	1.44	1.20	.24	.12	1.20	2.40	2.04	.48	....
New Orleans.											
12. March 10	.72	1.08	1.20	.60	.60	.60	.96	2.04	3.60	1.20	.24
13. March 18	1.32	.60	1.68	4.20	3.24	1.56	2.04	1.56	1.08	.72	.30
14. April 9	1.80	3.00	3.84	4.80	3.96	.72	.48	....	....	....	....
15. April 14	.48	2.04	2.76	1.92	.48	.36	1.44	2.04	.36	.96	.24
16. Sept. 2	.48	.60	.72	1.08	1.20	1.44	1.92	3.60	3.60	2.64	1.38
Savannah, Ga.											
17. April 24	.60	.60	.36	.24	.60	3.00	2.64	1.56	.84	.72	.54
18. July 7	.24	.36	3.00	4.20	3.00	1.80	.60	.12	.12	.12	.12
19. Aug. 18	3.00	3.00	2.40	3.00	.60	....	....	....	....	....	....
20. Aug. 26	.60	.36	.84	1.44	1.32	2.88	4 20	3.36	2.40	2.64	.36
Vicksburg, Miss.											
21. April 13	.48	1.44	2.40	2.88	.72	1.44	.72	.72	.72	.72	.30
22. June 6	.36	.60	3.24	3.00	2.40	2.40	.72	.24*	.24*	.48*	.24*
23. Oct. 22-23	2.28	3.12	1.92	.48	.36	.48	.48	....	....	....	....
Wilmington, N.C.											
24. Aug. 3	.60	4.80	3.00	1.80	1.92	.12	.12	.12	....	....	....
Norfolk, Va.											
25. June 9	3.00	1 80	1.80	5.40	2.04	1.08	1.08	1.08	....	....	....
26. June 22	1.20	3.24	3.48	4.08	.72	.48	....	....	....	....	....
27. July 16	60	3.36	3.00	2 64	.84	.96	.72	....	....	....	....

*Partly estimated.

TABLE I (continued).

CENTRAL AND NORTH CENTRAL CITIES. PERIODS IN MINUTES.

	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-60
Chicago, Ill.											
1. May 25	.12	.96	5.16	6.60	2.28	.36	.24	.12	......	......	......
2. Aug. 6	1.20	2.40	.72	3.12	3.36	1.08	.60	1.56	......	......	......
Cincinnati, O.											
3. July 20-21	1.68	1.92	1.44	1.56	3.24	2.16	.60	.84	.48	.36	.24
Cleveland, O.											
4. Apr. 30	3.36	3.60	3.60	3.00	1.20	1.80	1.32	48	......	......	......
5. June 8	.48	1.80	3.60	3.60*	3.00*	3.24*	3.24	1.20	.60	.36	......
Denver, Col.											
6. July 25	.60	3.00	3.60	2.16	2.04	.84	......	......	......	......	......
Detroit, Mich.											
7. June 25	1.80	3.60	4.80	1.80	.84	.84	......	......	......	......	......
8. July 26-27	4.56	2.28	.72	3.36	2.64	2.04	1.56	2.40	.84	.36	.30
Dodge City, Kan.											
9. Apr. 16	.60	1.20	3.00	3.00	1.80	2.04	1.80	.96	60	......	......
10. July 18	2.28	1.92	2.88	2.28	1.56	1.08	.72	.60	......	......	......
Indianapolis, Ind.											
11. May 25	3.60	2.40	4.80	.36	.96	......	......	......	......	......	......
12. Sept. 18	.60	1.80	2.64	1.56	3.00	2.40	3.60	2.40	1.80	.96	.30
Kansas City, Mo.											
13. May 31	9.60	3.00	......	......	......	......	......	......	......	......	......
14. July 18-19	.60	1.20	3.00	3.00	4.20	3.60	2.64*	2.40*	1.80*	1.44*	1.38*
Little Rock, Ark.											
15. June 2	3.00	3.00	3.00	2.40	.48	.36	.36	......	......	......	......
16. Oct. 29	.72	3.24	1.56	1.68	.72	.48	.36	.36	.36	.36	.54
Louisville, Ky.											
17. June 23	2.40	5.40	6.40	1.20	......	......	......	......	......	......	......
18. July 4	.72	1.08	6.60	6.00	3.84	2.16	2.40*	1.92*	1.92*	1.92*	1.92*
Nashville, Tenn.											
19. May 31	.60	.36	1.44	1.32	1.08	2.88	1.80	1.32	2.64	1.20	......
20. July 2	.60	1.68	3.00	1.92	1.44	.48	.24	.24	.60	1.44	1.44
21. July 12	1.44	2.16	3.60	2.64	2.76	.72	.12	.12	.12	.12	.30
Omaha, Neb.											
22. Aug. 15	4.20	4.20	4.80	4.20	2.04	......	......	......	......	......	......
Pittsburg, Pa.											
23. Aug. 13	.84	2.16	3.00	4.20	2.40	.96	.96	.96	.96	.84	1.56
St. Louis, Mo.											
24. May 27	.96	1.08	1.92	1.92	2.76	1.56	.96	.72	.72	2.16	.60
25. May 27	2.76	5.16	48	......	......	.12	......	......	.60	.84	2.16

	0-5	5-10	10-15	15-20	20-25	25-30	30-40	40-50	50-6		
St. Paul Minn.											
26. Aug. 4	1.20	4.32	4.56	4.80	2.40	1.68	......	......	......	......	......
27. Aug. 9	.72	1.56	2.40	2.40	.24	.84	2.04	1.80	.84	......	......

*Partly estimated.

From the records given, the following general observations may be drawn as to the laws of rainfall during the period of great intensity:

First.—Storms in the beginning have a short period of rapid increase in rain rate, and later a less rapid decrease in intensity.

Second.—Storms of extreme intensity during the first few minutes are usually of shorter duration than those which increase in intensity more gradually.

Third.—There is usually less fluctuation in the intensity of storms during the latter end than during the earlier stages of them.

Fourth.—Rains that give the greatest and most prolonged rainfall are those which increase in intensity at the start comparatively gradually, but they are less frequent than those of greater intensity and shorter duration.

Fifth.—The envelope of all the storms is not a straight line, but a curve resembling an hyperbola; or, in other words, the longer the duration the less the intensity proportional to that duration.

Sixth.—The liability to severe storm intensities is about the same in all parts of the United States lying east of the Rocky Mountains, though the annual rainfall may vary greatly.

The expected rain rate for any given length of time is most conveniently represented by an algebraic equation, in which y is the ordinate representing the rate of precipitation in inches per hour and t the duration of the storm in minutes of time. On this basis Professor Talbot proposes two equations (Fig. 4),—viz, $y = \frac{360}{30 + t}$, which gives an intensity not likely to be exceeded more than two or three times in a century, and $y = \frac{105}{15 + t}$, which give a value for y that may be exceeded every two or three years.

Kuichling's equations for probable maximum rainfall rate are $y = 2.10 - 0.0205t$ for storms lasting from fifteen minutes to one hour, and $y = 0.99 - 0.002t$ for storms of longer duration than one hour.

The Talbot form of equation seems to conform more nearly to the law of changing rain rate than do the formulas of Kuichling. If an equation is desired that will give a value of y which will not likely be exceeded more than once in every twelve or fifteen years, we may use $y = \frac{180}{30 + t}$. Comparing the values of y thus given with the maximum rates occurring at Washington for a period of sixteen years, it will be seen that the formula gives a curve nearly coincident therewith. Additional curves will be given under the discussion of run-off formulas.

RUN-OFF.

The ratio existing between the quantity of water precipitated and the quantity which finds its way immediately into the sewers depends upon several conditions, and the laws governing them. The quantity of water which will accumulate at a given point in a sewer depends upon, first, the size and shape of the area drained; second, upon the nature of the surface; third, upon the inclination

of the surface of the ground; fourth, upon the amount of moisture contained in the soil at the beginning of the rain; fifth, upon the rate of precipitation; sixth, upon the relative directions and velocities of the advancing storm and the water flowing in the sewer.

SIZE AND SHAPE OF DRAINAGE AREA.

The larger the territory tributary to the sewer the larger will be the total discharge, and the longer will be the time required to concentrate the flood discharge at the outlet. Before the water from the remoter parts reaches the sewer a considerable quantity of that falling on the nearer portions will have been carried away. On a large territory a greater percentage of the rain will soak into the soil, or evaporate, than on a small territory, and hence less will immediately reach the sewer. The shape of the land drained has also an important effect upon the rate at which the flood discharge will reach the sewer. A long, narrow strip of country will manifestly charge a sewer less heavily than one of square or circular form.

NATURE OF THE SURFACE.

The more impervious the surface, either from the character of the soil or by reason of buildings, pavements, etc., the greater will be the proportion of the total rainfall that will immediately reach the sewer.

INCLINATION OF THE SURFACE.

Obviously, the steeper the slope the quicker will the water find its way into the water courses, and hence the greater will be the volume which the sewer must carry.

MOISTURE CONTAINED IN THE SOIL.

When the ground is dry the first water that falls is absorbed, and a considerable quantity of run-off can usually take place only when the upper layers of the soil have become nearly or quite saturated. During the colder seasons of the year heavy rains sometimes occur when the ground is frozen, and may even augment their volume from melting snow. These floods are sometimes the most difficult for a sewer system to carry off. If a heavy rain has immediately preceded, so as to thoroughly saturate the soil, the subsequent precipitation will nearly all flow into the sewer, and is thus the severest test upon a system.

RATE OF PRECIPITATION.

A slow, drizzling rain will either be largely absorbed or will reach the sewers so gradually as to produce but slight flooding. On the other hand, a short, severe dash, even though the soil may be dry, will flow off very rapidly, and may cause great damage unless adequate provision has been made in the capacity of the sewers. The study of these sudden downpours forms one of the most important elements in the design of sewers.

DIRECTION AND VELOCITY OF STORMS.

This element in the problem is believed to have been first noticed by our fellow-member, Mr. C. G. Force, Jr. It is evident that if a storm advances in the same direction that the water in the sewer flows a greater flood wave will be formed, and a larger sewer will be required than if their movements are in contrary directions. Again, if the storm travels more rapidly than the water in the sewer, while the directions of their movements coincide, the first water which reaches the sewer will always be in the rear of that which falls nearer the outlet, and so will not combine with the latter to form as large a storm wave in the sewer as would be formed if their rates of movements were the same. In like manner, if the storm advances less rapidly than the water flows, the flood wave in the sewer will precede the flood wave at the front edge of the storm, and, as in the last case, the maximum accumulation of water will not occur. If the movement of the storm is at right angles to the direction of the flow in the sewer the storm moves across the path of the flowing water, and we have the ordinary case of the water from the lower portions of the territory being discharged before that from the upper portions reaches the outlet. No abnormal accumulation of the water can thus occur.

It is clear, therefore, that, in order to produce the greatest rate of discharge, the storm must travel in the same direction that the water flows and at the same velocity. We will now endeavor to establish a mathematical expression for the volume of run-off.

GENERAL FORMULA FOR RUN-OFF.

In order to be entirely general it would be necessary for the formula to contain a factor for each of the six foregoing elements. For simplicity, we can omit the fourth element, the amount of moisture in the ground at the beginning of the storm, and the sixth, the direction of the storm movement, because, for safety, it is advisable in using rain formulas for sewerage purposes to consider the

ground to be saturated, or nearly so, at the beginning of the storm, and to consider the direction of the storm movement to be taken into account by varying the intensity of the rain rate. We can also omit the element of slope, if the rain rate be taken for a length of time sufficient to concentrate the water from the entire area, since the slope is involved implicitly in the time element. Our formula will thus contain three variable factors. If we let f = the percentage of the rainfall that enters the sewer, the remaining portion of the rainfall soaking into the ground or evaporating, y = the rate of rainfall in inches per hour during the interval required to concentrate the water from every part of the area drained, and A = the area of the drainage surface considered, in acres, we have the following general formula for the total number of cubic feet per second from the total area drained: $Q = F\ (f\ y\ A)$; that is to say, Q is some function of the variables f, y and A. The shape of the territory does not enter into the formula, as it is assumed that the formula will be applied only to areas the lengths of which are not more than three or four times their breadths. The problem then is to find the proper numerical values of the factors and the form of the function in which they severally enter the formula.

AREA.

If the ground were perfectly impervious the entire amount of water precipitated, less evaporation, would ultimately drain into the sewer. Under these conditions, if we let T represent the duration of the storm in hours and Q^1 the total quantity of discharge in cubic feet for a given area A, and y, as before, the rate of rainfall for the time T, we have $Q^1 = \frac{43{,}560.\ A\ y\ T}{12} = 3630\ A\ y\ T$; but since there are 3600 seconds in one hour, and since it is usually more convenient to state the quantity of water discharged in terms of the rate of discharge, as so many cubic feet per second, we have $Q = \frac{Q^1}{3{,}600\ T} = 1.0083\ A\ y$, or, sufficiently accurate for practical purposes, $Q = A\ y$. But this discharge could only be realized when the area is perfectly impervious, and when the rain rate continues unchanged for a period of time sufficient to cause each square foot of the area to contribute to a given point at the same time.

POROSITY OF THE SURFACE.

In no case, except for small areas, such as paved courts, roofs, etc., do we find the surface entirely impervious. In ordinary

practice only a portion of the total rainfall is discharged immediately into the sewer. A part of the water soaks into the soil to be drained off gradually, or to be evaporated without ever reaching the sewer. Experience shows that this absorption for short storm dashes, such as tax a sewer most severely, is independent of the slope of the surface or of the area of the district drained. The percentage of the total rainfall reaching the sewer immediately is affected, however, by the rate at which it is precipitated. Since, in sewer designing, maximum conditions must be provided for, we usually are interested only in the percentage of the total rainfall discharged when the heaviest rain occurs for which provision is to be made.

It is frequently assumed that this percentage in some way is proportional to the density of population, and tables have been prepared which are supposed to give the relationship. In my opinion such comparisons are untrustworthy and misleading. It is necessary to distinguish clearly between business and residence districts. In business areas no such criterion can be applied, because the population varies so widely between night and day.

In the business center of Cleveland, such as the blocks adjacent to Superior street and west of the Public Square, the actual paved or roofed surface is from 88 per cent. to 100 per cent. of the entire area. Where there are small open spaces they may be considered impervious, because they occur only in small spots, and are so compacted that during a heavy rain practically all of the water falling thereon will flow directly to the sewer. In such districts, therefore, the population criterion is not admissible.

Estimates of the impervious area,—*i.e.*, paved and roofed surfaces,—in the residence district of the city, where all of the lots are of good size and occupied by at least one house, vary from 25 to 50 per cent. of the total area. For districts where the lots are not so large the impervious area may run as high as 70 per cent. In sections intermediate between business and residence districts, those occupied by flats, boarding houses, etc., the impervious area will be still greater. In these estimates the entire street is supposed to be impervious, for if there be a narrow strip of lawn between the sidewalk and the curb, being narrow and having transverse drainage, the water flows to the gutter nearly as quickly as it would if paved, since all our calculations suppose the soil to be saturated.

In order to show that the proportion of impervious area is not entirely dependent upon the density of population, the following estimates of the relationship are given:

Block Boundaries.	Pres. Imp. %.	Ultimate Imp. %.	Pop. per Acre.
1. Sibley, Cedar, Case, Kennard,...............	28.8	28.8	23
2. Clinton, Alley, Kentucky, Duane,..........	46.7	50.	23
3. First, Slater, Quincy, Scoville,...............	24 2	43.7	35
4. Jersey, Penn, Bridge, Carroll,..................	50.	67.8	39
5. St Clair, South alley, New alley, Muirson,	38.	51.	52
6. Laurel, Sterling, Central, Scoville,.........	22.6	53.5	55
7. Rockwell, Tneresa, Bond, Erie,.............	65.2	68.5	81

No. 1 is a block with fair size lots with large houses. Nos. 2 and 4 are well-to-do residence property. Nos. 3 and 6 are occupied by a greater number of smaller dwellings. Nos. 5 and 7 are dense old residence areas contiguous to the business quarter. A glance at these figures will show that the impervious area is governed by other factors than density of population.

The value of f is made up of two elements: first, the actual impervious area which contributes all of the falling water to the sewer directly; and, second, a certain percentage of the water falling on the pervious area. For example, suppose a case where the actual impervious area were 40 per cent. of the whole, and suppose that one-fourth of the water falling on the permeable surfaces unites with that from the impervious area to form the run-off, then we have for the value of f, $f = .40 + \frac{.60}{4} = .55$. The proportion of the water flowing off immediately from lawns and similar surfaces ranges probably from .15 to .25, but hard-beaten surfaces of yards devoid of grass in the close quarters of a city will doubtless discharge nearly all of the rainfall directly into the sewer. The safest method is to make trial calculations of the actual impervious areas in the portions of the city where conditions have reached something near their final state, and from values so obtained, after adding a certain percentage as just explained, adopt a value for f suitable to the case in hand. Each city must be governed largely by local circumstances regarding this factor. However, for safety in business districts the factor should not be taken less than 1.00, and, as will be shown in the case of some of our own sewers, 1.25 would probably be a safer value to use.

For residence areas it is probable that a value exceeding .75 will rarely be necessary. For those districts that are neither business nor residence, but partake of the conditions of both, the engineer's judgment must be the guide. For sparser areas smaller values will be used, but for cities of metropolitan dimensions it is not safe to assume that the population of any region will long remain sparse.

RATE OF RAINFALL.

It becomes necessary to fix the proper value of y to be used in the above equation. Assuming for the moment that Talbot's equation, $y = \frac{105}{15 + t}$, gives the correct intensity for a given case, before we can fix the value of y we must find the length of storm required to concentrate the water from the whole area at the given point. In order to do this we must take account of the inclination of the territory, make a rough preliminary calculation of the probable value of Q, obtain the required size of sewer to carry the volume Q, from which, knowing the grade of the sewer, the velocity therein can be calculated. An estimate of the distance that the water must travel from the remotest point of the area under consideration must be made, and this distance divided by the velocity will give the length of time required for the water in transit. To this time must be added an estimated interval required for the water to flow along the ground to the gutters, and from thence to the catch basins. Having the time thus given, by the above equation or by any other, the value of y is calculated. This value may now be introduced into the formula, and the value of Q determined.

This, however, is a slow and tedious process, and one that the engineer is reluctant to use. A shorter way to the same result is therefore desirable. Of the many formulas which have attempted to abridge the above process, the Burkli and McMath formulas are the best known and the most frequently used. The Burkli formula is

$$Q = f\,r\,\sqrt[4]{s}\;A^{\frac{3}{4}},$$

and the McMath formula is

$$Q = f\,r\,\sqrt[5]{s}\;A^{\frac{4}{5}}$$

in which r is the intensity of rain rate for a small interval of time to be determined, and s is the slope of the sewer in feet fall per 1000 feet.

Writing these equations in the form $Q = f\,y\,A$, we have, for the Burkli formula,

$$Q = f\left(\frac{r\,\sqrt[4]{s}}{\sqrt[4]{A}}\right)A$$

in which

$$y = \frac{r\,\sqrt[4]{s}}{\sqrt[4]{A}};$$

and for the McMath formula,

$$Q = f\left(\frac{r\,\sqrt[5]{s}}{\sqrt[5]{A}}\right)A$$

in which
$$y = \frac{r \sqrt[5]{s}}{\sqrt[5]{A}}.$$

As the value of the time, t, is involved only indirectly in s and A, further reductions are necessary in order to complete the transformations and to thus be able to compare the value of y derived from the above equations with observed rainfall records, and so ascertain their relative merit.

For the present, assume a rectangular area the width of which is x feet, and the length of which is 3x feet. We then have $A = \frac{3x^2}{43,560}$, from which $x = 120\sqrt{A}$ approximately. The greatest distance which the water must flow to reach the lowest corner of the area is the length of one side and one end, or 4x; therefore the maximum distance to be traversed by the water is $480\sqrt{A}$. Now the velocities of water in various sizes of sewers having an inclination of one to the thousand when flowing full or half full is, for 1 foot 6 inch sewer, 1.5 feet per second; 2 feet sewer, 1.9 feet per second; 3 feet sewer, 2.5 feet per second; 4 feet sewer, 3.1 feet per second; 5 feet sewer, 3.6 feet per second; 6 feet sewer, 4.1 feet per second. If we take 2.5 feet per second as the average velocity for moderate size areas, having a slope of 1 foot per 1000 feet, and assuming, for the present, that the velocity for other slopes are proportional to the $\sqrt{s}$, the velocity for any slope will be, roughly, $2.5\sqrt{s}$ feet per second, or $150\sqrt{s}$ feet per minute. The time, t, in minutes, necessary therefore to concentrate the water from the area A will be

$$t = \frac{480\sqrt{A}}{150\sqrt{s}} = \frac{3.2\sqrt{A}}{\sqrt{s}}.$$

This value of t being the time only which is consumed by the water in flowing the distance 4x, we must add thereto some arbitrary number of minutes to represent the time required for the water to accumulate on the surface and to flow along the gutter to the sewer.

Supppose, therefore, a unit area, A, of one acre, 121 feet wide and 360 feet long, which is not unlike the shape of an ordinary city lot. Suppose that 5 minutes be required for the water to accumulate upon the ground and to flow 120 feet to the gutter; and if the velocity in the gutter be 2 feet per second, 3 minutes will be required for it to flow along 360 feet of gutter to the sewer; in all 8 minutes. Or, if the lot fronts with the end to the street, allowing say 2 minutes for the water to accumulate on the surface, and one foot per second as its rate of progress over the surface to the gutter, we have 2 minutes plus 6 minutes, or 8 minutes, as

before, required to reach the sewer. It is probable therefore that from 8 to 10 minutes should be added to the time as above determined in order to get the required time to concentrate the water in the sewer. We therefore have the equation

$$t = \frac{3.2\sqrt{A}}{\sqrt{s}} + 8$$

from which $$A = \left(\frac{t-8}{3.2}\right)^2 s.$$

Substituting the value of A in the equation

$$y = \frac{r\sqrt[4]{s}}{\sqrt[4]{A}}$$

and reducing we have $$y = \frac{1.79\, r}{\sqrt{t-8}}.$$

By the same method for the McMath formula we obtain

$$y = \frac{1.59\, r}{\sqrt[5]{(t-8)^2}}.$$

These equations give a value of y for each changing value of t, and are therefore rain formulas which can be compared directly with records of actual rainfall. The factor r, however, remains to be interpreted, and its proper value assigned.

The Burkli and McMath formulas each involve four independent variables, A, f, s and r, and we may therefore assign any values to A, f and s without changing the value of r. If, therefore, $A = 1$, $f = 1$ and $s = 1$, the formula reduces to $Q = r$, in which, as already explained, r is the intensity of rain rate for the length of time necessary to concentrate the water from one acre of land, or, as already shown, the intensity for an 8 or 10-minute dash.

Let us assume that $r = 4$, a value justified by inspection of Figs. 1 to 4, and we have the equation of Burkli and McMath

respectively, $$y = \frac{7.16}{\sqrt{t-8}}$$

and $$y = \frac{6.36}{(t-8)^{\frac{2}{5}}}.$$

The completely reduced Burkli formula becomes then $Q = f\,y\,A$,

in which $$y = \frac{7.16}{\sqrt{t-8}}$$

and in which $$t = \frac{3.2\sqrt{A}}{\sqrt{s}} + 8$$

and the McMath formula becomes $Q = f\,y\,A$, in which

$$y = \frac{6.36}{(t-8)^{\frac{2}{5}}}$$

and in which $$t = \frac{3.2\sqrt{A}}{\sqrt{s}} + 8.$$

These formulas are consistent and rational, providing one thing further is verified,—viz, the correctness of the value of t as given by the preceding equations. In order to make an actual test of the value of t the following table is constructed, in which the calculated times are given for various areas for the concentration of the water by the various methods shown.

Table showing actual and calculated times, t, required to concentrate the water from various areas:

		No. of Acres Drained.					
		1600	400	100	75	50	25
Actual	$s = 1, t = \frac{8\sqrt{A}}{\text{Velocity}} + 8$	73	46	30	28	25	22
Burkli and McMath	$s = 1, t = \frac{3.2\sqrt{A}}{\sqrt{s}} + 8$	136	72	40	35	31	24
Proposed	$s = 1, t = \frac{3.2\sqrt{A}}{s^{3/4}} + 8$	136	72	40	35	31	24
New York Diagrams,	$s = 1, t = \frac{3.2\sqrt{A}}{s^{0.9}} + 8$	136	72	40	35	31	24
Actual	$s = 2, t = \frac{8\sqrt{A}}{\text{Velocity}} + 8$	55	36	24	22	20	18
Burkli and McMath	$s = 2, t = \frac{3.2\sqrt{A}}{\sqrt{s}} + 8$	99	53	31	28	24	19
Proposed	$s = 2, t = \frac{3.2\sqrt{A}}{s^{3/4}} + 8$	84	46	27	24	21	18
New York Diagrams,	$s = 2, t = \frac{3.2\sqrt{A}}{s^{0.9}} + 8$	76	42	25	23	20	17
Actual	$s = 4, t = \frac{8\sqrt{A}}{\text{Velocity}} + 8$	42	29	20	19	17	16
Burkli and McMath	$s = 4, t = \frac{3.2\sqrt{A}}{\sqrt{s}} + 8$	72	40	24	22	19	16
Proposed	$s = 4, t = \frac{3.2\sqrt{A}}{s^{3/4}} + 8$	53	31	19	18	16	14
New York Diagrams,	$s = 4, t = \frac{3.2\sqrt{A}}{s^{0.9}} + 8$	45	26	17	16	15	13
Actual	$s = 16, t = \frac{8\sqrt{A}}{\text{Velocity}} + 8$	27	19	15	14	13	12
Burkli and McMath	$s = 16, t = \frac{3.2\sqrt{A}}{\sqrt{s}} + 8$	40	24	16	15	14	12
Proposed	$s = 16, t = \frac{3.2\sqrt{A}}{s^{3/4}} + 8$	24	16	12	11	11	10
New York Diagrams,	$s = 16, t = \frac{3.2\sqrt{A}}{s^{0.9}} + 8$	19	13	11	10	10	9

The first value of t tabulated for each slope is found by making a preliminary estimate of the total amount of storm water discharged from each area on the given slope. From this quantity, with the slope, the diameter of the sewer required and the average velocity of flow therein is obtained. Assuming in each case that the length is three times the width, the total distance traveled, 4x, divided by the mean velocity will give the time occupied by the water flowing in the sewer, and finally, 8 minutes are added to give the total time required for concentrating the water at the lower end of the sewer.

By comparing the values of t, tabulated, it will be seen that the equation reduced from the Burkli and the McMath formulas give good results for small areas, but as the size of the area increases the error becomes considerable. The effect of the error is to make the quantity Q, or storm water discharged, from large areas too small. It was apparently for the purpose of correcting this tendency in the Burkli formula that induced McMath to propose his modification of the equation; and the same difficulty is sought to be overcome by the formulas in use at Washington, where excessively large values of the constants are used.

The key to the difficulty lies in the equation for t, and much of this tendency to error is eliminated by the following further modification. Let

$$Q = f\left(\frac{r\sqrt[4]{s}}{\sqrt[6]{A}}\right)A = f\,r\sqrt[4]{s}\,A^{\frac{5}{6}}.$$

Here, again, $$y = \frac{r\sqrt[4]{s}}{\sqrt[6]{A}}$$

in which, by a process similar to that already used,

$$t = \frac{480\sqrt{A}}{150\sqrt[4]{s^3}} + 8 = \frac{3.2\sqrt{A}}{s^{\frac{3}{4}}} + 8.$$

from which $$A = \left(\frac{t-8}{3.2}\right)s^{\frac{3}{2}}.$$

Substituting the value of A in the equation for y and reducing, we have

$$y = \frac{1.47\,r}{\sqrt[3]{t-8}}.$$

And if, as before, r = 4, we have

$$y = \frac{5.88}{\sqrt[3]{t-8}}$$

in which $$t = \frac{3.2\sqrt{A}}{s^{3/4}} + 8.$$

In the above table the values of t are given by this formula also, and these values are observed to correspond much more closely to the correct ones than do those deduced from the Burkli and McMath formulas.

The element of rain intensity given by the "New York Diagrams," published in the recent report of the Sewerage Commission of the city of Baltimore, also agrees much more closely with the true time than do either the Burkli or McMath formulas. This formula, using the same notation as before, is

$$Q = f r s^{.27} A^{.85} = f \left(\frac{r s^{.27}}{A^{.15}} \right) A$$

in which $$y = \frac{r s^{.27}}{A^{.15}}.$$

By repeating the process used in the former cases, the equation for time becomes

$$t = \frac{480 \sqrt{A}}{150 s^{.9}} + 8 = \frac{3.2 \sqrt{A}}{s^{.9}} + 8$$

from which $$A = s^{.27} \frac{(t-8)^2}{10.24}.$$

Substituting the value of A in the above equation for y, and reducing, gives

$$y = \frac{1.418 r}{(t-8)^{.3}}$$

and if $y = 4$, the equation is

$$y = \frac{5.67}{(t-8)^{.3}}$$

in which, from above, $$t = \frac{3.2 \sqrt{A}}{s^{.9}} + 8.$$

The values of t for the various slopes and areas are given in the table above. It will be noticed that these values, in some instances, agree very closely with the true values of the time, and while it gives more accurate values of the time for flat slopes than the formula proposed, for the steeper slopes the values become too short. In other words, the tendency of the formula is rather to exaggerate the effect of slope on the time required to concentrate the water at the sewer. The proposed formula, in addition, has the advantage of being easier to apply to problems in actual practice. It will be noticed, however, that none of them give the correct time for large areas on very flat slopes. This is partly that, for such large areas, 2.5 feet per second is too small a mean velocity on a slope of one in a thousand to assume for the flow of the water

over the entire area, and partly from inherent defects in all of the expressions for the time, as it is difficult to express all the varying conditions in a simple formula. The error, however, for either of the latter formulas is not serious, for by consulting Fig. 4, in which several rain curves are platted, it will be seen that for areas large enough to require an hour or more to concentrate the water a considerable error may be allowed in the value of the time, t, without seriously affecting the value of the rain rate, y.

Now, by using Fig. 4 as an over-sheet to Figs. 1, 2 and 3, the comparative merits of the formulas are rendered apparent by the rain records of the year 1896. Comparison is also made with the Talbot, Kuichling and other formulas thereon shown. While logically it may be preferable to use a formula directly in the form of $Q = f\ y\ A$, yet, owing to the labor of obtaining the value of t from which y can be correctly determined, practically there is a gain in using the formula involving y indirectly in the values of s and A.

In the preceding equations the value of the factor r taken is 4. While this is a value in excess of that usually used in the Burkli and McMath formulas, notwithstanding the larger results obtained by the formula involving the 5-6 power of A instead of the $\frac{3}{4}$ or 4-5, the results for conditions prevailing in such cities as Cleveland appear to be none too large. By Figs. 1, 2 and 3 it will be noticed that very many storms are of greater intensity than those given by the curve, and the question has constantly to be asked, "How often is it allowable to permit sewers to be surcharged?"

During the years 1895 and 1896 an inspection was made of a large number of the sewers of the city to determine, as far as possible, the cases where sewers had been surcharged, and in other cases how deep the water had flowed. In some cases the markings along the sides of the sewers were uncertain, but for the most part they were fairly definite. From such data it is not possible to determine when a certain flood depth occurred, but the date is of secondary importance to the fact that a given depth had at some time been actually attained. General conclusions, therefore, can be drawn from these observations which are of considerable value.

In many of the main sewers of the city the lateral branches are entirely inadequate to carry the water flowing to them, and hence in these cases the rate of run-off cannot be determined. In fact, there is not at present in the city of Cleveland any large drainage area in which the lateral system, as a whole, is adequate to converge all of the run-off water as fast as it seeks admission to

the sewers. There are a few small areas in which the lateral systems are of fair size, and from these only can conclusions of importance be derived. The following are a few of the cases investigated:

Franklin avenue sewer, west of Harbor street, drains about 22 acres on grades of about .25 feet per 100 feet. The factor f is about .60. The sewer, No. 3,* and No. 4, has been required to flow with a surcharge of about 2 feet, and has discharged about $1\frac{1}{2}$ cubic feet per acre. Taking f, .60, and s, 2.5, and applying the formula, $Q = f\,r\,\sqrt[4]{s}\,A^{\frac{5}{6}}$, the deduced value of r becomes from 2.3 to 2.6.

Franklin avenue sewer, from Franklin Circle to Taylor street, like the portion west of Harbor street, is medium residence territory, with grades of about .40 per 100 feet. The sewer is No. 3 and No. 4, draining about 25 acres. The sewer has flowed with from 4 to 8 feet of surcharge, making its actual discharge difficult to calculate. Even if it flowed only its maximum capacity when nine-tenths full, the volume discharged would be from 1.3 to 2.2 cubic feet per acre. With this condition, taking f, .60, and s, 4.0, the value of r in the above formula would be from 2.3 to 3.8, but, since the sewer flowed under considerable head, the discharge must have been in excess of these amounts. That the congested condition of the sewer was not caused by backwater from portions of the sewer lower down is shown by the fact that in both of the above cases the depth of the water increased as we ascend the line of sewer.

The Waverly avenue system is greatly overcharged, the water in the manholes over the entire middle and upper portions standing from 4 to 10 feet deep. It is not possible to calculate the amount of water conveyed, but it is evident that the entire system has been

*The egg-shaped sewers in use in Cleveland, except No. 3 below, were designed by Mr. C. G. Force, Jr., Member American Society Civil Engineers, and have been in use for the last 25 years. The principal elements of those referred to in this paper are as follows:

No. of Sewer.	Width. Ft.	Height. Ft.	Area, Sq. Ft.	Hydraulic radius, (sewer full).
3,	2.10	2.66	4.33	0.58
4,	2.54	3.23	6.35	0.70
5,	2.95	3.74	8.55	0.82
6,	3.33	4.23	10.90	0.92
7,	3.70	4.69	13.39	1.02
8,	4.04	5.12	16.00	1.12
9,	4.37	5.54	18.72	1.21
10,	4.69	5.94	21.54	1.29

greatly overtaxed. Even if it had carried only its maximum flow when nine-tenths full, we should have at Randall street, just north of Lorain, No. 4 sewer, grade .25, Q, 25 cubic feet, f, .60, s, 2.5, and A, 44 acres. Therefore, r equals 1.4. Randall street, south of Bridge street, is a No. 6, with a grade of .25; therefore the discharge is 55 cubic feet. With f at .60, s at 2.5 and A at 92 acres the reduced r is 1.7. Harbor street: The sewer is No. 7 sewer, on .30 grade; therefore $Q = 79$ cubic feet. With $f = .60$, $s = 2.5$, $A = 132$, r becomes 1.8. Taylor street, north of Franklin: Sewer is No. 7, on .56 grade; therefore $Q = 108$ cubic feet. With f .60, s 2.5, A 200, r is found to be 1.75. It is evident, notwithstanding the fact that the laterals are nearly all inadequate, that the value of r, denoted by the capacity of the sewer when surcharged, must have exceeded 2.

The Lawrence street system, with areas not exceeding 155 acres, and with sewers up to No. 10 size on .25 grade, the main sewers have flowed with depths of water at the manholes of from 8 feet to 11 feet. The area tributary and south of Payne avenue is only sparsely occupied by residence property. North of Payne avenue the dwellings are of medium density, while along Payne avenue and Superior street there are some business districts. Taking the average of the territory, the impervious area probably does not exceed 20 per cent. If one-fourth of the remaining territory contributes to the flood discharge the value of f is .40. For safety, call it .50; a value greater than that cannot be allowed. Taking s at 3, by the approximate calculated capacities of the sewers, the values required for the factor r in the formula are from 3.5 to 4.5. For this area the lateral system is much better than it is for the preceding cases mentioned, hence the larger run-off.

Detroit street sewer, from Duane to Pearl: The area is narrow and mostly directly tributary to Detroit street, and is occupied by business property merging into contiguous residence portions. The impervious area is about .60, requiring a value of f of .75, and value of s, 3. For block between Pearl and Hanover the tributary area is about 33 acres. Sewer is No. 9, on .40 grade, with flood depth of 3.3, thus giving 85 cubic feet discharge. The calculated value of r, then, is 5. By similar process, for the successive blocks to the west, the values calculated for r are 3.1, 3.9 and 5.7. The sewer thus actually carries off, as determined at the several localities, 1.9, 2.5 and 4.5 cubic feet per acre for areas ranging from 4 to 33 acres. This sewer at no time was surcharged, and hence may be presumed to have carried off all of the storm water as fast as it reached the sewer.

Seneca street sewer drains a total of about 46 acres above Summit street. The area is almost entirely occupied by large business blocks, and might be expected to carry off as large a volume of run-off as any area of like size in the city. All of the streets are paved, and the actual area covered by roofs and pavements is probably 85 per cent. of the total. Just above Summit street there is a $5\frac{1}{2}$-foot circular brick sewer, on a .50 grade per 100 feet. The sewer has flowed 5 feet deep, or with a discharge of 222 cubic feet per second. This it at the rate of 4.8 cubic feet per acre. If, now, we take $f = 100$, $s = 3$, $A = 46$ and $Q = 222$, r becomes 7.0. At the manhole between Fountain and Noble streets the sewer is 5 feet diameter, on .50 grade, and has flowed full, thus giving 160 cubic feet per second discharge. The tributary area is about 31 acres, giving a run-off rate of 5.2 cubic feet per acre. With the same constants as before, the value of r in our formula becomes 7.0. The sewer immediately north of St. Clair street is a 5-foot circular sewer, on a 0.50 grade, and has flowed 4 feet deep, giving a discharge of 159 cubic feet per second. The tributary area is some 22 acres, therefore the unit run-off is 5.5 cubic feet per acre. Using the same constants again, r is 7.4. Contiguous areas are all fairly well sewered, and it seems doubtful that any great amount of flood water has reached Seneca street sewer from other districts.

What conclusions can be drawn from the foregoing observations? The first, and most obvious, is that, notwithstanding the poor grades and sewer junctions in some cases, the usual formulas and unit volumes for run-off, at least as applied to Cleveland, are entirely too small. The Seneca and Detroit street sewers were designed in 1892, and built in 1893. If it be assumed, as seems probable from the rain records, that the flood heights as recorded occurred during one of the storms of 1896, it is obvious that the rate of run-off greatly exceeds the rate at which the rain was precipitated. It would appear, therefore, that in densely built-up sections of a city the actual flood discharge may considerably exceed the rain intensity. If such be the case, it is possible that the water accumulates upon the surface until a condition of hydraulic head is produced, which forces the water forward into the sewer as a flood wave with more than its normal flowing rate.

The unit value of run-off to be adopted must be decided after a consideration of all the circumstances. It is doubtful if a value less than 4 for the factor of r should be used in a rain formula, and for business districts even a greater value would be advisable. So far as investigated, in every case where the sewer is unable to carry

at least a rain rate of 2, as used in the proposed formula, the sewer has been greatly surcharged. This has been the case even where the territory was only sparsely improved, and even where the laterals were unable to concentrate the entire run-off at the sewer. For areas of less than 10 or 15 acres in dense business districts it is doubtful if any formula can have much value. It is as safe to assume that a given number of cubic feet of water will flow from each acre per second, but with larger areas a continuation of a uniform rate of discharge no doubt tends to exaggerate the sizes of sewers required, and for such cases reduction formulas are useful.

In conclusion, the gaugings which have been mentioned are not supposed to have exact scientific value. It is also probable that the year 1896 had more than the average number of heavy storms. In Cleveland the year past was much below the average, there not occurring an instance of even moderately heavy rainfall.

It should be stated, however, that if curve No. 10 of Fig. 4 be applied to the rain records collected by Professor Talbot it will be seen that a considerable percentage of the heavy rains tabulated by him exceed the intensity shown by the curve, and are about the same proportion that is shown by the charts herewith given. The foregoing gaugings show to what degree some of our sewers are actually taxed, the date when such conditions occurred being of secondary importance; and, while exact gaugings have not been taken, the results show clearly that a greater run-off must be expected than in some cases has been provided for.

DISCUSSION.

Mr. M. E. Rawson.—Mr. Parmley has certainly treated the subject in a very much more comprehensive way than I could have done, and I have nothing to add to what he has said. He has helped to design the Walworth Run sewer, the largest sewer we have ever built here, and about as large as is built in any other city. Three sections of the Walworth Run sewer are in progress of construction. We are building another large sewer, a part of the intercepting sewer system of the city, about one mile of which in the western part of the city is completed. The statements made in this paper are not guesses, but are the results of an elaborate study. To meet with success, the practitioner must be able intelligently to apply his remedies to the case, and I think that has been thoroughly done in this instance.

Mr. C. G. Force, Jr.—A study of the records of actual rainfalls will, I think, justify the use of the 5-6 exponent of A in the run-

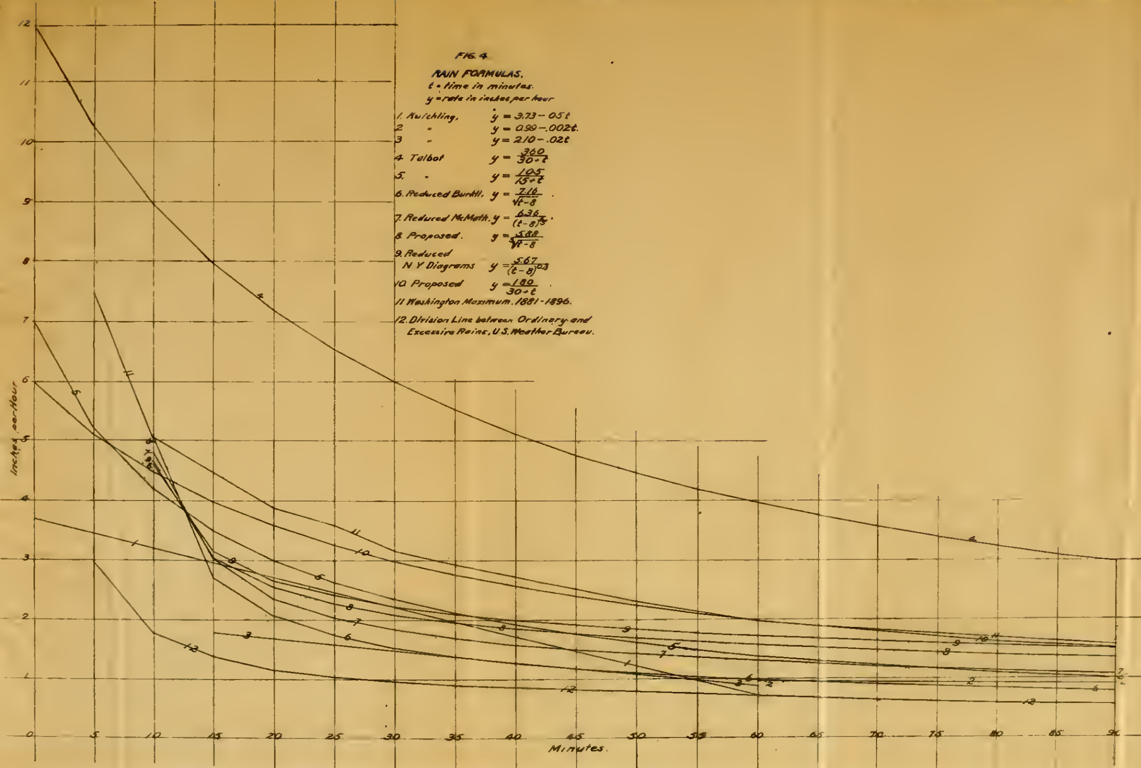
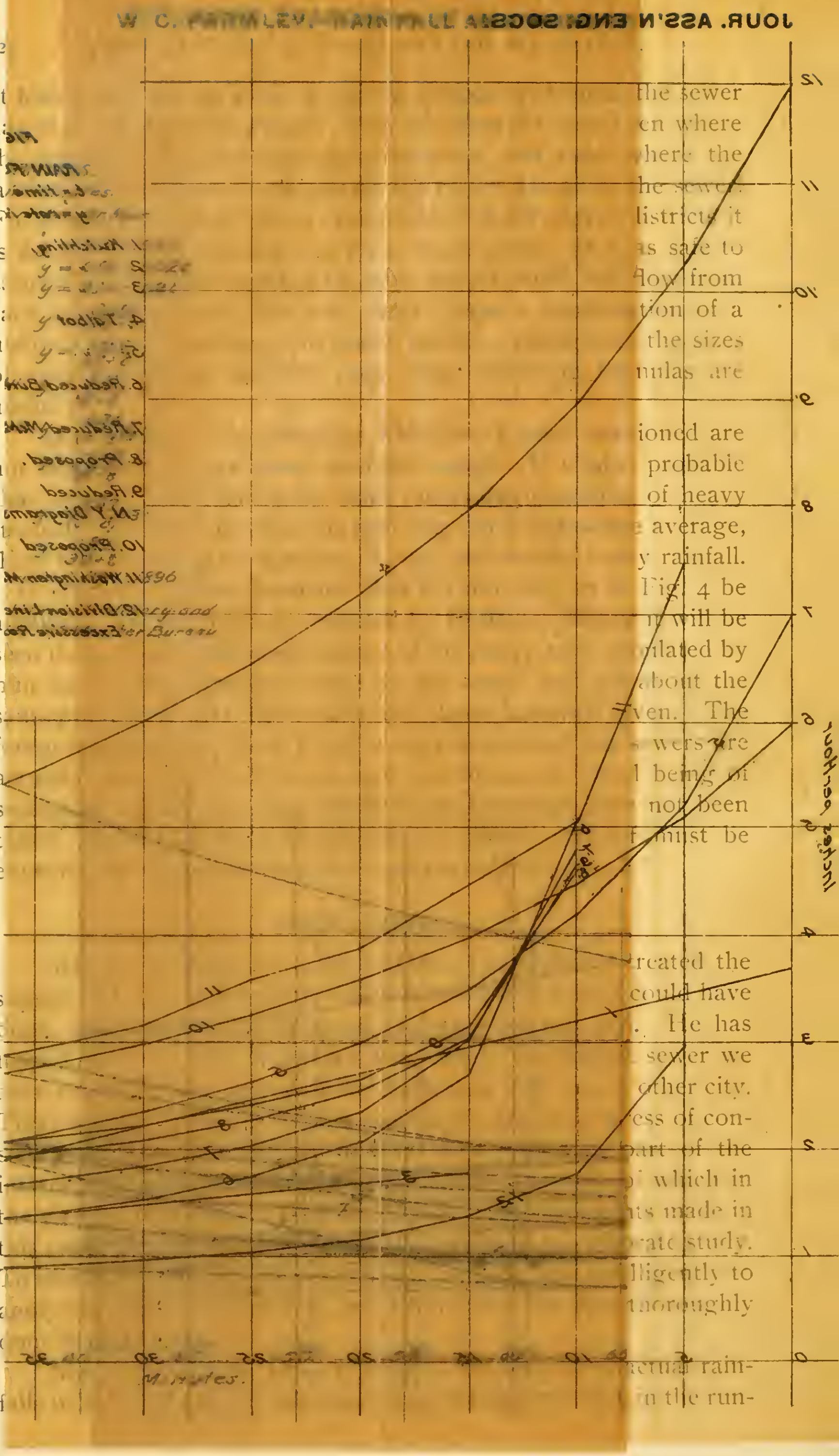


FIG. 4
RAIN FORMULAS.
t = time in minutes.
y = rate in inches per hour
1. Kuichling, $y = 3.73 - .05t$
2 " $y = 0.99 - .002t$.
3 " $y = 2.10 - .02t$
4 Talbot $y = \frac{360}{30+t}$
5. " $y = \frac{105}{15+t}$
6. Reduced Burkli. $y = \frac{7.16}{\sqrt{t-8}}$.
7. Reduced McMath. $y = \frac{6.36}{(t-8)}$.
8. Proposed. $y = \frac{5.88}{\sqrt[5]{t-8}}$
9. Reduced N Y Diagrams $y = \frac{5.67}{(t-8)^{0.3}}$
10. Proposed $y = \frac{180}{30+t}$.
11 Washington Maximum. 1881-1896.
12. Division Line between Ordinary and Excessive Rains, U.S. Weather Bureau.
Inches per Hour
Minutes.



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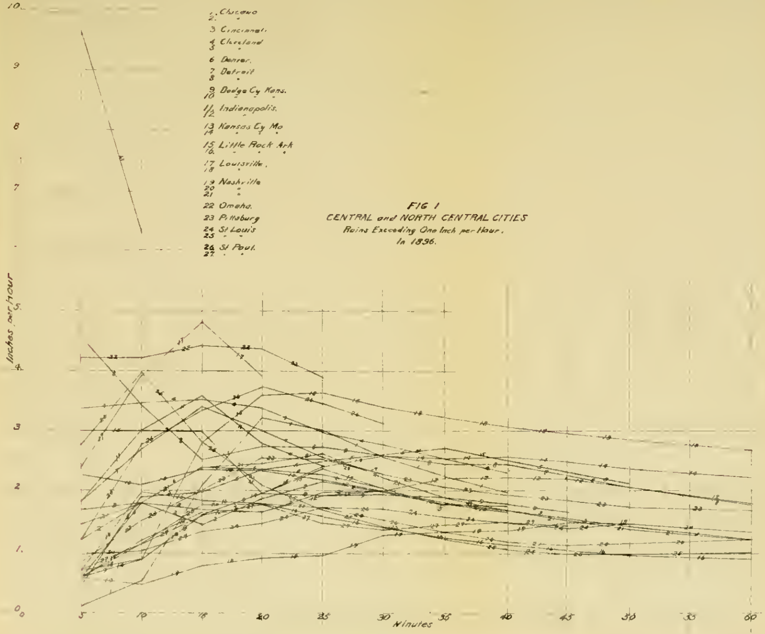
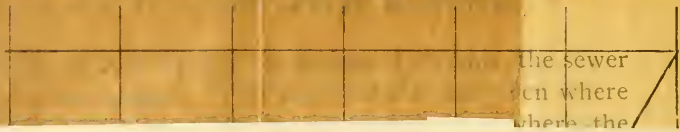


FIG 1
CENTRAL and NORTH CENTRAL CITIES
Rains Exceeding One Inch per Hour.
In 1896.



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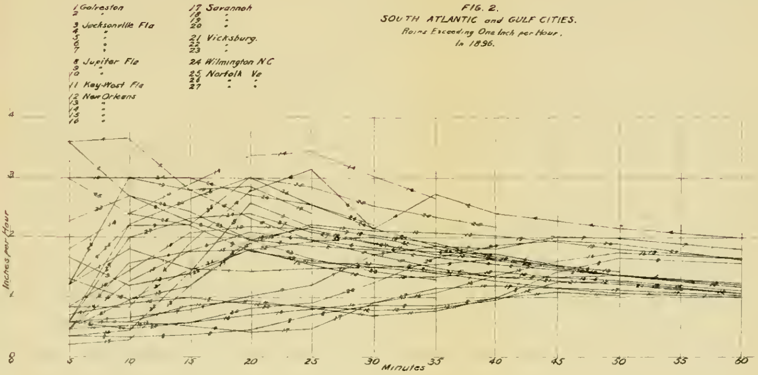
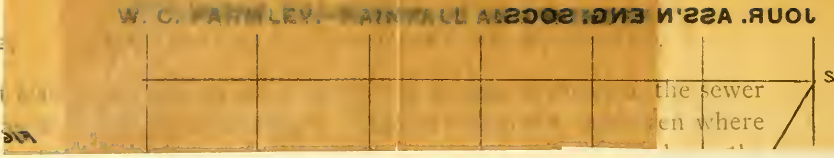


FIG. 2.
SOUTH ATLANTIC and GULF CITIES.
Rains Exceeding One Inch per Hour,
In 1896.



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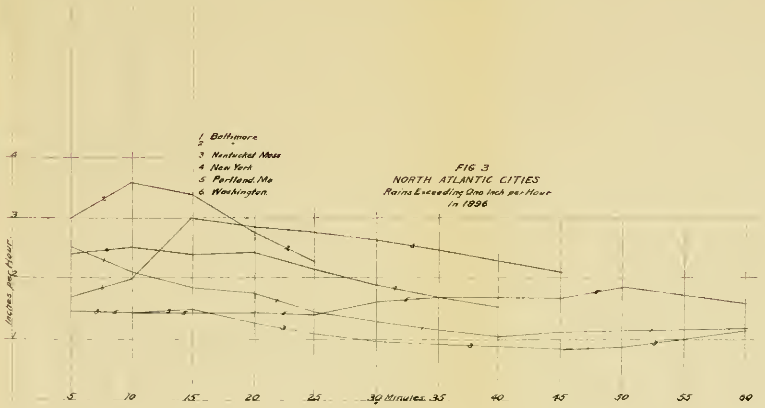
1 Baltimore
2
3 Nantucket Mass
4 New York
5 Portland. Me
6 Washington.
FIG 3
NORTH ATLANTIC CITIES
Rains Exceeding One Inch per Hour
In 1896
Inches per Hour.
4
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2
1
5
10
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20
25
30 Minutes. 35
40
45
50
55
60

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off formula instead of the $\frac{3}{4}$ exponent commonly used in the Burkli formula, or even the 4-5 exponent proposed by Mr. McMath, of St. Louis. The effect is to increase the estimated run-off from large areas over that obtained by the use of the other exponents. This I wish particularly to emphasize.

The author of the paper gives prominence to the time element, and, I think, correctly. Heretofore this feature has not been given the weight it should have received.

I am in accord with the paper, and believe it is a step toward the correct solution of the important problem of run-off.

EFFECTS OF HEATING AND WORKING ON IRON AND STEEL.

By Prof. H. E. Smith, Member of the Engineers' Club of Minneapolis.

[Read before the Club, March 14, 1898.*]

To the engineer, who has to deal so extensively with the metals iron and steel, the processes of their manufacture and the manifold physical qualities which they may be made to assume are of interest. Their varying characteristics during and after casting, rolling, forging, annealing or tempering form a fruitful source of study and investigation, while some knowledge of the changes that these materials undergo in chemical and physical qualities during these operations is essential to their successful use.

The various kinds or grades of steel may be included in three general divisions—crucible cast steel, open-hearth steel and Bessemer, or pneumatic steel. Each of these classes now has quite a distinct field of usefulness, and there is but little competition, except, possibly, between the Bessemer and open-hearth steels.

The cost of manufacture of crucible steel is greatest, and there is little dispute as to the pre-eminence of the desirable qualities of this material; but, for many purposes, Bessemer or open-hearth steels are all that can be desired. A good wagon spring can be made from Bessemer steel, that will last as long as the wagon, and it would be foolish to pay more for a longer-lived crucible steel spring, for it is not likely that the old spring would be placed on a new cart years later.

On the other hand, there are certain uses, as the manufacture of metal-cutting tools and in some parts of machinery, for which the crucible steel has no competitor.

Bessemer steel is probably the cheapest of all grades of steel, and, for the manufacture of good rails and for certain structural purposes, it has no rival. It has its limitations, however, due to the method of manufacture, which offers the greatest liability for the absorption of undesirable elements, as oxygen, nitrogen, etc. The rapidity with which the conversion of the cast iron into steel takes place also presents a barrier to the manufacture of a material of uniform quality.

For fine boiler plate, armor plate, steel castings and some forms of structural work, open-hearth steel has established its superiority to either of the others.

*Manuscript received March 21, 1898.—Secretary, Ass'n of Eng. Socs.

It is not my purpose, however, to speak at length on the various methods of manufacture of these steels, but to confine myself, chiefly, to the effects of working and heat treatment which result in bringing out the highest qualities of the iron or steel, or which partially, or totally unfit the metal for the use intended. Steel is very sensitive to heat, and the size and structure of the grain correspond to every degree of heat that is applied.

The evidences of the degree of heat to which the steel has been subjected are permanent, unless influenced by some external force, such as hammering or rolling, and offer a ready means by which the producer can detect a careless workman, or by which the steel user can decide whether the article furnished him has been properly handled in the processes of manufacture.

Let us consider some of the characteristics which a piece of tool or cast steel can be made to assume by the application of heat. If a bar of tool steel be nicked at intervals, then heated so that the temperature varies uniformly from that of the air at one end, to that at which the corners just begin to melt, at the other end, then quenched and the bar broken at the successive nicks, the structure of the bar will be found to have undergone varying changes.

Beginning at the end which was not heated above the temperature of the air, and passing to each successive piece, we find the grain or structure of the steel to be the same as that of the original bar until we reach the portion which was heated to a full red. Here the grain suddenly changes to an extremely fine and nearly amorphous form, and beyond this point the crystalline structure becomes more and more coarse.

There appears to be a maximum degree of coarseness, or size of grain, for each temperature, varying with the composition of the metal and rising with the sectional area and with the temperature and time of exposure.

The rate of cooling also has some influence on the size of the crystals, especially in large forgings.

A bar of steel 1.5 inches square, when quenched from a very high temperature, shows coarse crystals on the outside. They become rigid so quickly that they preserve the form acquired at the high temperature. The interior of the bar is flaky and might even be called fine grained, much finer, indeed, than if the bar had been cooled slowly. This is probably due to the internal stresses, which tend to break up the crystalline structure of the center of the bar. It appears to be a general rule that, other things being equal, the finer the grain the greater the ability of the steel to resist shock. Thus the means of acquiring and preserving this

grain are of great importance, and not less important are those of avoiding the coarse grain. This fine grain may be obtained in two ways, or under two sets of conditions; one, by suddenly cooling the steel from the molten state, and the other, which is of more practical benefit to the engineer, by producing a change in the carbon from the non-hardening to the hardening form, at the full red heat. The first method probably breaks up the coarse structure due to the high temperature by the intense internal strains induced, while the second causes a sudden rearrangement of the crystals, which seems to be so violent as to efface all previous crystallization.

Forging and rolling iron or steel oppose and break up crystallization, if they are performed while the iron is at or above the red heat.*

But, if forging or rolling be completed at a high temperature and if the piece be then slowly cooled, the higher the temperature at which the forging ceases, the coarser the grain and the worse the steel. Hence the importance of a low finishing temperature in this work.

The superiority of thin over thick forgings, which is usually attributed to the extra work performed on them, is probably due, in large part, to the usually low finishing temperature of thin or small pieces.

An experiment performed by a competent metallurgist serves to illustrate this fact. Three uniformly heated test bars, cut from a single ingot, were carefully rolled, one very fast, one normally, one very slowly. Their merit was found to be inversely as their finishing temperature.

As power, hence cost, is saved by rolling or forging at high temperatures, means have been proposed of accelerating the cooling after forging has ceased. Such a method is used in the Coffin rail process, where the rails are immersed in water or have streams of water play on them immediately after coming from the rolls, until their temperature falls to the dark red, from which point the rails are cooled slowly to the temperature of the air. If, when a bar is broken cold, the fracture presents a coarse grain in one part and a fine grain in another, it shows uneven heating. If the grain is coarse on one side and fine on the other, it indicates that the workman has exposed one side of the bar to a much greater heat than the other. If the outside of a forging shows a fine grain and the interior a coarse grain, it indicates that the piece has been

*Rivets are said to fail at the head, which is not struck, rather than at the struck head. The blows of the riveter prevent and overcome crystallization and consequent brittleness.

worked by too light blows of the hammer or by light passes in the rolls; the outside having been refined by the work, while the interior of the piece remained unaltered. On the other hand, if the piece shows a coarse structure on the outside and a fine structure within, it indicates that the piece has been heated too rapidly and not thoroughly, and has not had sufficient work expended upon it.

If the grain presents a heavy, dark tint, the steel has been finished too cold.

It will be found, on testing, that pieces of our experimental bar, which show the finest crystalline structure, exhibit the greatest ductility, toughness and shock-resisting power.

This fine grain is, then, very desirable in the finished product, whether it be rolled or forged iron or steel, or steel castings.

This structure *cannot* be obtained by any system of cooling the pieces, but *can* be produced by reheating, after cooling to the full red, and then cooling quickly. The more or less complete restoration of overheated and even burned steel may be accomplished by reheating to the red heat, followed by forging and then quickly "quenching" or slowly cooling.

It has been shown that, for every variation in the grain of a piece of iron, there is a difference in the specific gravity, which means, of course, a difference in volume. If, then, a piece of iron has an uneven grain, internal stresses must exist.

Fortunately, we have a ready means of relieving these stresses, in the fact that the metal will assume a grain or structure corresponding to the degree of heat, no matter what the previous condition of the iron has been. This change is usually accomplished by the process of annealing, which effaces the coarse structure, gives fine grain, increases strength and ductility, and raises the elastic limit. It also relieves the internal stresses due to previous working or uneven heating.

In cases of special forgings, as in the heads of eye-bars, it would seem to be wise to anneal the end, so as to remove the stresses which must exist between the unheated part and the part that was heated and forged.

In the manufacture of wire, frequent annealing is rendered imperative by the internal stresses and hardening effect caused by the working of the wire in the die plates.

The usual method of annealing is to heat the piece, after it has cooled, to the full red or to a medium orange color, and to allow the piece to cool slowly and uniformly.

On account of the tendency of steel to crystallize above the full red heat and also while the temperature is falling to the dark

red, the proper heat for annealing is the full red, followed by quickly cooling to the dark red and then slowly cooling through the remaining range of temperature.

The above treatment is applied to car axles and other steel forgings, by the Cambria Steel Co., of Johnstown, Pa.

Cherrioff gives the following as the results from three samples cut from the same bar of steel. After equal forging the samples were treated as follows:

A was slowly cooled.

B was reheated to a full red and then slowly cooled.

C was reheated to a full red, quenched to a dark red and then slowly cooled.

A broke under a single hammer blow.

B required five such blows.

C could be broken only by a blow of a five-ton steam hammer.

Rapid cooling produces hardness in steel, and the more rapid the cooling the greater is the effect. There seems to be an apparent exception to this rule in the so-called "water annealing" practiced by some forge men when doing a rush job. They heat the piece uniformly, up to the point where it will just show red in a darkened place, and then quench it. By this means, the hardening effect due to forging is only in part removed, in that the hardening effect of sudden cooling from this temperature is less than the softening effect after forging by the reheating. The piece is by no means in as good condition as it would have been had the usual method been applied to it.

It will also be found, on applying tests for hardness to the pieces of our experimental bar, that, beyond the point where the crystalline structure changes suddenly, the steel has become extremely hard, and especially very brittle toward the end that was exposed to the highest heat.

Chemical as well as physical change has also taken place in the steel. The carbon it contained exists, in combination, in at least two perfectly distinct modifications called cement and hardening carbon.

The chemical evidence of these two forms was first demonstrated by Faraday in 1822, when he found that steel, when suddenly cooled, dissolved completely in dilute, cool, hydrochloric acid, and, when the steel was annealed, it left a carboniferous residue. In the first case, the carbon is said to be in the hardening form, in the latter, in the non-hardening or "cement" form.

The exact difference between the two forms of carbon is not

definitely known, but their effects upon the qualities of the steel are quite evident.

The carbon in our samples will be found in the cement form in all the pieces that were not heated above the full red heat, and in the hardening form in all pieces heated above this temperature.

In annealed steel, practically all the carbon is in the cement form, while in hardened steel scarcely any of it is in that form, from which we infer that it is in the hardening state.

In tempered steel, an intermediate proportion is in the cement state.

In molten iron and steel, the carbon is probably in a condition closely related to the hardening carbon, since, on suddenly cooling from fusion, we find it chiefly in this form.

According to Brinnell's experiments, the change from cement to hardening carbon does not take place below the red heat, but occurs suddenly and completely at the red heat. This can be proven by heating a piece of steel, in which the carbon is initially in the cement state, up to nearly the red heat, and then quenching, when the carbon will be found still in the cement state; while, if quenched from the red heat or above, the carbon is found wholly hardening. On the other hand, if we heat a bar above the red heat and slowly cool it, the carbon remains in the hardening form until the temperature at which red just shows in the dark, when the carbon begins to change slowly to the cement form, and so continues until about the temperature of the air is reached.

That the transfer of carbon from the hardening to the cement form may occur at very low temperatures, is suggested by the reported fact that table knives gradually lose their hardness if habitually washed in hot water, or that razors, if used cold, retain their temper longer than if warmed before using, though for other reasons the razor may cut better while hot than while cold.

Other phenomena indicate an important chemical change at a temperature somewhere between the full red and the dark red heats.

The temporary magnetism, whether induced by an electric current or by another magnet, suddenly vanishes at this temperature, and its thermo-electric behavior is abnormal.

Here a remarkable evolution of heat takes place, known as the "after glow." This is accompanied by a marked rise in temperature, a sudden expansion and a great temporary increase of flexibility.

The late John Coffin, of the Cambria Steel Co., found that the expansion of a bar of iron, when cooling through this range,

increased greatly with the proportion of carbon. A four-foot bar with 0.90 per cent. of carbon, in cooling from an orange heat, contracted $\frac{1}{8}$ in., re-expanded $^1/_{32}$ in., then again contracted $^9/_{16}$ in. A similar bar with 0.17 per cent. of carbon contracted regularly during 45 seconds, then ceased to contract for 20 seconds, then again contracted. In iron containing a very small per cent. of carbon, no perceptible decrease in the regular contraction was noted.

An experiment which gives striking illustration of the violent rearrangement of the molecules of steel, when heated to the full red heat, was performed before the Philadelphia meeting of the American Society of Mechanical Engineers, November, 1887, by Mr. Coffin.

A piece of $\frac{1}{4}$-inch square tool steel was broken, the fresh fractures placed in close contact, the pieces inclosed in platinum foil to exclude the air and heated to the full red in the flame of a Bunsen burner. After cooling it was found that the pieces were very perfectly joined. A number of larger pieces, both soft steel and tool steel, were shown at the same meeting, that had been united in a similar manner, and which, by their color, sharpness and freedom from scale, indicated that they were united either much below the ordinary welding temperature or with the nearly perfect exclusion of oxygen.

Another critical temperature, for both iron and steel, is at the so-called "blue heat," which is from 450° to 600° F. Here, iron and steel are much more brittle than when cold or at redness. This heat, however, does not seem to leave any bad effect on the iron. But if the piece be worked in this range of temperature, it will retain the brittleness after cooling and show a great loss of ductility, as measured by the bending test, although it has not been conclusively proven that there is a loss of ductility when the piece is pulled apart by static tensile stress.

The poorer the iron, the more susceptible it is to the "blue heat." In other words, the poorer the iron, the more dangerous it is to work it at that heat. The danger to steel, at the "fatal blue," is more pronounced than in iron, but it exists, to a greater or less extent, in all grades of iron. It is also more noticeable in a descending than in an ascending heat, and is especially noticeable in work having sharp corners, which has been worked at the blue heat.

The loss of ductility and of shock-resisting power is not due to any incipient cracks, as can be proven by the restoration of the former qualities of the metal by reheating to redness or by anneal-

ing. Several experimenters have called attention to the increase of "blue shortness," or the effects of "blue heat," with the increase in percentage of non-ferrous elements present in the iron, but these reported facts have failed to be fully sustained by recent experiments. There seems to be some close relation between the effects of "blue shortness" and "coldworking," but the injurious effects of the former are more marked than those of the latter.

Soft steel plates, which have cooled to the blue heat while in the process of rolling, have been reported, by Bessemer and others, to have been shattered in the last passage through the rolls.

While blue-working lessens ductility, it is not always fatal to the metal. Examples may be cited in proof of this. In hand riveting the operator usually continues hammering while the rivet cools past this critical temperature, and yet few rivets have been known to fail from this cause alone. Shafting is often heated to blueness by a dry bearing, while under stress and shock, but is apparently uninjured.

Blue-working, without subsequent annealing, is prohibited in boiler work for the United States Navy, but not for hull work. Many good American and British engineers do not forbid blue-working in their practice.

Another phenomenon, exhibited by iron and steel when cooling from the molten state, is the evolution of large volumes of gas, which assist in the formation of blowholes and other imperfections against which the designing engineer has to contend. These gases have been found to be principally of nitrogen, hydrogen and carbonic oxide, and may be held in the iron in several conditions:

1. In chemical combination. 2. In solution. 3. In adhesion. 4. Mechanically retained.

In the first three conditions the gases are in a condensed form. This condition of the gas can be illustrated by some examples. A piece of charcoal will, at atmospheric pressure, absorb 90 times its own volume of ammonia gas. The ammonia could not possibly be still in the state of a gas, for, if it were, its pressure would burst the charcoal. Similarly, electro-deposited iron may hold 248 times its own volume of hydrogen. These gases are evidently in a liquid or solid form.

It appears that iron, when molten, freely absorbs nitrogen, hydrogen and carbonic oxide gases; and, in solidifying, evolves them, being no longer able to retain them. The escape of these gases is what gives the steel maker and foundry man their trouble, as gas, which is caught in the pasty mass of iron, forms minute bubbles, which enlarge, by accretions from the adjacent metal, into openings called blowholes. The gases in these openings, if unable

to swim to the top of the casting, cause the metal to swell or rise, or, if they escape, cause boiling and scattering, which produce unsound pieces.

Grey cast iron, which passes quickly from the liquid to the solid state, is less likely to form blowholes than white cast iron, which passes through a pasty condition, unfavorable to the escape of gases.

The less carbon, silicon and manganese an iron contains, the more does it tend to form blowholes. High carbon steel is usually comparatively free from blowholes, but is more liable to "piping," or the formation of openings at the center of the ingot, due to its greater contraction in cooling.

Irons containing large percentages of phosphorus, however, disengage gas much more violently and tend to produce unsound castings. The gas continues escaping for some time after the iron has solidified, and can be obtained from the minute cavities of all irons by subsequent borings which penetrate these openings.

Sir Henry Bessemer proved that the escape of gas from molten steel was largely governed by the existing pressure. When a partial vacuum was formed over the solidifying ingot, the evolution of gas was much more violent. If a pressure were produced the solubility of the gases in the iron was increased, and any gas which was evolved during solidification would be more promptly expelled. This process, which he called "liquid compression," was described by him in 1856. It remained, however, for Sir Joseph Whitworth to put this knowledge into practical use. In his process, the steel is cast in a special mold or flask of great strength and so arranged that the gases can escape. The metal, while solidifying, is subjected to a pressure, occasionally reaching 20 tons per square inch of horizontal cross section. This pressure hastens the discharge of the evolved gases and prevents, to a considerable extent, the formation of blowholes, and, by producing a flow of metal to the contracting center of the ingot, partially overcomes piping, the ingot being actually compressed about one-eighth of its longitudinal dimensions. The Bethlehem Iron Co. uses this process in the steel castings from which large shafts and other structures are forged.

It has not been the intention of the writer to do more, in this brief paper, than to outline some of the physical and chemical changes which may take place in iron and steel while being formed for the many purposes of the engineer.

There are in this field many phenomena which should be investigated, and the possibilities which may be derived from a more complete knowledge of this most valuable metal are far-reaching.

BRICK PAVING.

By Irving E. Howe, Member of the Engineers' Club of Minneapolis.

[Read before the Club, March 14, 1898.*]

A description of the construction and statement of cost of the brick paving on Seventh street, South, between Hennepin avenue and Seventh avenue, South, in the city of Minneapolis, done during the season of 1897.

It will not be necessary, nor of any particular interest to the members, to give an account of the preliminary work of receiving bids, etc. Suffice it to say that bids were received and rejected three times.

These bids were received according to specifications on file in the office of the City Engineer, which called for a repressed vitrified brick paving, on a six-inch concrete foundation, ten years' guaranty, 10 per cent. cash retained and 15 per cent. surety bond. The prices bid were from $1.99 to $2.04 per square yard. These were considered too high, and the City Engineer was instructed to buy the material in the open market, to pave said Seventh Street, South, with vitrified paving brick on a six-inch concrete foundation according to the same specifications upon which the bids had been received.

Work was begun on August 24, just five days after receiving the instructions, and was finally completed October 8, practically six weeks from the time of beginning.

In the meantime, while the removing of the old cedar block paving and grading were in progress, prices were obtained for the various kinds of material to be used; crushed stone of a suitable quality was difficult to obtain in the time needed. This was all that delayed the work. The stone was finally procured from three sources, at prices ranging from $1.00 to $1.275 per cubic yard, delivered on the street.

The material for filling, to bring the street to the proper grade, and the sand for concrete and cushion, were obtained as the work progressed from various sources where they could be purchased most cheaply.

The prices paid ranged from 10 cents per load to 35 cents per cubic yard, delivered on the street. 1992 barrels of Milwaukee cement at 75 cents, and 1296½ barrels of Mankato cement at 78 cents per barrel were used.

*Manuscript received March 21, 1898.—Secretary, Ass'n of Eng. Socs.

A very stiff price for brick was maintained by the various companies. The prices obtained, after considerable labor and correspondence, were as follows:

Iowa Brick Company, Des Moines, Iowa, $15.00 per thousand, guaranteeing 57 bricks to the yard, no other guaranty.

Des Moines Brick Mfg. Co., $15.00 per thousand, no guaranty.

The Galesburg, Ill., Paving Brick Company would give no price.

Barr Clay Co., Streator, Ill., $15.50 for one-half the amount only, guaranteeing 57 bricks to the yard, no other guaranty, and shipment to begin after thirty days.

Purington Paving Brick Co., Galesburg, Ill., $16.00 per thousand, guaranteeing 56 bricks to the yard. The company also gave a ten-year guaranty to replace all defective brick within the period. This price was so reduced that the net cost to the city was $15.54¼ per thousand, equal to 87 cents per square yard, or only 1½ cents per yard more than the lowest bid. The Purington bricks were considered to be worth more to the city, and they were accordingly bought.

The bricks were shipped very promptly and were handled in a very satisfactory manner by the C. B. and N. Railroad Company.

This cuts no small figure when it is considered that it took 198 cars to furnish the brick. They arrived at the rate of about ten cars per day.

The bricks were delivered and piled on the sidewalk and boulevard outside of the roadway along the street in advance of the work, so that there should be no travel on the paving before it was finally finished. These bricks were the most uniformly burned lot I have ever seen. The small bricks (2½ x 4 x 8 inches) were used on all the work, except the block between Sixth and Seventh avenues, South, where the large bricks or blocks (3 x 4 x 9 inches) were used. As this last size is what most of the brick people claim they are going to manufacture next year, it was thought best to give them a trial, as the company agreed to furnish them at the same price per square yard.

A contract was made with John Murphy, of Columbus, O., for filling and grouting the joints of the paving with his patent "Murphy Grout" for 17½ cents per square yard. Owing to the unsatisfactory manner in which some of the material set up, only about one-half the work was paid for, waiting until next season for final adjustment, as it was too late in the season to do anything about it at that time.

The method of laying pavement was as follows:

After removing the old paving and planking, the street was brought to the proper subgrade, allowance being made for ramming and rolling. This subgrade was then rolled with a seven-ton horse roller, until every portion had been sufficiently compressed. Sections around manholes and other places that could not be reached by the roller were rammed by hand. Upon the foundation, thus prepared, was laid the concrete, which was mixed on three boards, twelve feet square, arranged abreast of each other across the street; enough sand for one "mix" (in proportions of 1 cement, 2 sand, and 5 stone) was dumped on the front half of the broad; cement was then added to this and mixed dry, then water was added and the whole was brought to a smooth mortar, before adding the stone. This mixture was taken off the board with hoes, the workmen, six in number to each board, standing in the rear of the board and pulling toward it, so that by the time it came off the board it was thoroughly mixed, and in the meantime another "mix" had been added to the front of the board ready for them to step forward and begin over again. After the concrete was taken off the board, it was levelled and tamped until it was brought to the proper elevation. The concrete was then allowed to set not less than eight days.

The concrete foundation was covered with a one-inch layer of sand. To bring the surface of this sand cushion to a perfect grade, conforming to the crown and grade of the street to be finished, one-inch strips were nailed to the concrete every twelve feet, extending across the roadway from curb to curb. An iron-shod straight-edge or scraper was placed on the strips and dragged across the street, bringing the sand to a plane between the strips, then one strip was taken up and moved ahead of the other twelve feet, and the same process was repeated. Upon this cushion the bricks were laid, the principal care being to keep the joints close and the courses straight. After a block had been laid, the roller was put on, and rolling continued until the bricks were firm and solid and presented an even surface. All bricks broken by the roller were replaced and the pavement again rolled. The grout filler was then put on by flooding and sweeping with brooms, made especially for the work. This was allowed to set for five days before throwing the street open to travel.

In other cities, trouble has been had with brick paving buckling, due to expansion and contraction by change of temperature. To obviate this trouble, half-inch expansion joints, extending across the roadway from curb to curb and consisting of California

asphalt and maltha, were placed about 150 feet apart. So far this method has given excellent results.

An average crew of sixty-five men was employed. The minimum wages paid for labor was $1.75 per day, and the total amount expended for labor was $4585.00. The detail cost of the work was as follows:

Removing old paving	$0.035	per	square	yard.
Grading	0.032	"	"	"
Concrete	0.467	"	"	"
Planking concrete, lumber and miscellaneous	0.008	"	"	"
Brick	0.870	"	"	"
Hauling	0.038	"	"	"
Cushion	0.018	"	"	"
Laying brick	0.032	"	"	"
Murphy grout	0.175	"	"	"
	$1.675	"	"	"

This price of $1.675 per square yard, being 31½ cents below the lowest bid, and being the price at which the assessment was made, makes a saving of about $5400.00 to the city, and gives it a paving with a ten-year guaranty for bricks constructed with more care and at greater expense than it would be reasonable to expect of a contractor.

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AN INVESTIGATION OF THE STRENGTH OF COLUMNS, LEADING TO SOME NEW FORMULAS.*

BY CARL G. BARTH, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read before the Club, March 16, 1898.†]

WHEN I for the first time became acquainted with the development of the Rankine-Gordon formula for the strength of columns, I was much surprised to find it resting on a very unsatisfactory analysis. I accordingly set to work on an independent investigation, and soon received sufficient encouragement to go ahead, with reasonable assurance of accomplishing something. As a result, it is the purpose of this paper to submit a new and purely rational formula for the proper working load on a column, which rests on arguments to which it is thought that no exception can be taken by any one who will try to follow them in an unbiased spirit.

In the first place, it seems impossible to conceive of such a thing as a rational formula for the *ultimate* strength of an ideal column, for we can assign no reason why an ideal, centrally loaded column, however long, should yield in any other way than a short one; that is, why it should yield under any load less than the direct crushing resistance of the material; for even the load determined by Euler's formula, though it will maintain any initial lateral deflection that may have been given to the column, cannot of itself give rise to any such deflection.

*The most essential part of this paper was presented orally to the Engineers' Club of St. Louis, May 5, 1897.

†Manuscript received March 21, 1898.—Secretary, Ass'n of Eng. Socs.

Evidently, therefore, all that we can look for in a rational column formula is that it shall enable us to determine a load that will subject a fairly well-made and properly arranged column to no undue stress, even if that load should accidentally be applied at some reasonable distance out of center.

The formula herein to be proposed is of that nature, and has been derived by considering *all the uncertainties* of a practical column (such as possible imperfections in its material and form, and any possible eccentric displacement of the load) as *equivalent to* a certain amount of *initial eccentricity* of the load on an otherwise *ideally perfect* column.

Thus, when the permissible working stress f per square inch of section of an exceedingly short practical column, as illustrated in Fig. 1, a, is taken as equal only to the fraction $\frac{1}{n_c}$ of the elastic limit F of the material in compression, then this is considered equivalent to allowing for a possible eccentric displacement v_c of the load such that the maximum stress that would be produced by the load thus displaced on a perfect column of the same dimensions, would not exceed F; as illustrated in Fig. 1, b.

Denoting the cross-section of the column by A, and its radius of gyration by r, its moment of inertia I becomes $A r^2$; and if we further denote the distance from the center of the section to its most remote point by a, we may write

$$P_c v_c = p_c A v_c = S_c \frac{I}{a} = S_c \frac{A r^2}{a},$$

which then gives the stress due to the bending moment alone,

$$S_c = p_c \frac{v_c a}{r^2}$$

Adding this to the stress p_c due to the direct compression of the load, we get the total maximum compressive stress, which shall not exceed the elastic limit F or $n_c f = n_c p_c$. Thus we get

$$F = n_c p_c = p_c + S_c = p_c \left(1 + \frac{v_c a}{r^2} \right).$$

Solving with respect to v_c this may accordingly be written

$$v_c = (n_c - 1) \frac{r^2}{a}. \qquad (1.)$$

in which expression n_c is thus the factor of safety allowed on the elastic limit of the material, for a simple, direct crushing load.

Referring now to Fig. 2, it is evident that, for a column of some length, any initial eccentricity v of the load P will cause a lateral deflection $\triangle$, so that the effective eccentricity or lever-arm of the load with respect to the section at the base of the column, will be $(v + \triangle)$. The maximum bending moment will thus be $P (v + \triangle)$.

Now, it will be proved in the appendix to this paper that the deflection Δ depends on the initial eccentricity v, the load P, the length of the column l, the radius of gyration of the cross-section r, and the modulus of elasticity of the material E, in such a manner that we may write

$$v + \Delta = v . \sec\left(\sqrt{\frac{P}{AE}} . \frac{l}{r}\right) = v . \sec\left(\sqrt{\frac{p}{E}} . \frac{l}{r}\right)$$

This significant relation between Δ and v will perhaps more readily be realized from its geometrical representation in Fig. 3, which shows how exceedingly rapidly the deflection increases with the expression $\sqrt{\frac{p}{E}} \frac{l}{r}$.

If we put
$$\sqrt{\frac{p_e}{E}} \frac{l}{r} = \frac{\pi}{2}$$
and solve with respect to p_e we get

$$p_e = \frac{\pi^2}{4} E \left(\frac{r}{l}\right)^2. \qquad (3.)$$

which will be recognized as Euler's formula for this case.*

As secant $\frac{\pi}{2} = \infty$, we now readily see why this formula gives a load that is necessarily destructive to a practical column; it (the load) tends to indefinitely increase any initial eccentricity it may have, however small this may be.

On the other hand, we also realize *that a very low factor of safety on this load will make the column abundantly secure against any undue deflection*, as the secant of an angle drops with enormous rapidity when the angle recedes from 90^0, or $\frac{\pi}{2}$.

Evidently, then, as for an exceedingly long column Euler's load becomes so small that the direct compressive stress due to the same may be neglected, such a column would with perfect safety carry a load but little less than that load; and though, on account of the necessary imperfection of a practical column, Euler's load requires to be divided by some suitable factor of safety, n_1, even this need be but moderate; for, considering the bending stress produced by the load, we will find that this factor n_1 will be equivalent to allowing for an exceedingly large initial eccentricity of the load on an otherwise perfect column.

Denoting this permissible working load on an exceedingly long column by $P_1 = p_1 A$, we may accordingly write, for a

*Evidently the factor 4 in the denominator disappears for a column pivoted at both ends, since its action would be the same while its length would be doubled.—J. B. J.

column fixed at one end and free to turn and to move laterally at the other, as in Fig. 2,

$$p_1 = \frac{p_e}{n_1} = \frac{\pi^2}{4n_1} E \left(\frac{r}{l}\right)^2 \qquad (4.)$$

Putting p_1 for p in (2) we further get

$$v_1 + \triangle_1 = v_1 \sec\left(\sqrt{\frac{p_1}{E}}\,\frac{l}{r}\right) = v_1 \sec\left(\frac{\pi}{2\sqrt{n_1}}\right) \qquad (5.)$$

The maximum bending moment then becomes

$$P_1(v_1+\triangle_1) = p_1 A\,(v_1 + \triangle_1) = \frac{\pi^2}{4n_1} E\left(\frac{r}{l}\right)^2 A \times v_1 \sec\left(\frac{\pi}{2\sqrt{n_1}}\right)$$

and putting this equal to the resisting moment, and the stress produced equal to the elastic limit F, we may write

$$\frac{\pi^2}{4n_1} E\left(\frac{r}{l}\right)^2 A\, v_1 \sec\left(\frac{\pi}{2\sqrt{n_1}}\right) = F\frac{I}{a} = F\frac{A\,r^2}{a},$$

which, solved with respect to v_1, gives

$$v_1 = \frac{4\,n_1}{\pi^2}\cos\left(\frac{\pi}{2\sqrt{n_1}}\right)\frac{F}{E}\left(\frac{l}{r}\right)^2 \times \frac{r^2}{a}. \qquad (6.)$$

This is, accordingly, the initial eccentricity that the load P_1 may be given without producing a bending stress exceeding the elastic limit of the material.

v_1 is thus, for a column so long that the direct compressive stress may be neglected, what v_c in (1) is for a column so short that its deflection may be neglected. But for even a very low value of n_1, v_1 will become very great, as it is proportional to the square of the length of the column, and will thus represent ample allowance for reasonable imperfections in the material and form of a practical column.

We now conclude that the general expression for a suitable eccentricity v to be allowed for on a column of any length, must be such as to become equal to v_c for an exceedingly short column, and at least approximately equal to, and not less than, v_1 for an exceedingly long column; or, more correctly, equal to v_c for $\frac{l}{r} = 0$ and equal to v_1 for $\frac{l}{r} = \infty$. But as v_1 becomes 0 for $\frac{l}{r} = 0$, and ∞ for $\frac{l}{r} = \infty$, these requirements are fully satisfied by putting $v = v_c + v_1$, or

$$v = \left[n_c - 1 + \frac{4\,n_1}{\pi^2}\cos\left(\frac{\pi}{2\sqrt{n_1}}\right)\frac{F}{E}\left(\frac{l}{r}\right)^2\right]\frac{r^2}{a} \qquad (7.)$$

Substituting this value of v in (2) we get

$$v + \triangle = \left[n_c - 1 + \frac{4\,n_1}{\pi^2}\cos\left(\frac{\pi}{2\sqrt{n_1}}\right)\frac{F}{E}\left(\frac{l}{r}\right)^2\right]\frac{r^2}{a} \times \sec\left(\sqrt{\frac{p}{E}}\,\frac{l}{r}\right) \qquad (8.)$$

In order now to determine the load $P = p\,A$, that acting on the lever-arm $(v + \triangle)$ will produce a total maximum compressive stress equal to the elastic limit F of the material, we first write

$$P\,(v + \triangle) = p\,A\,(v + \triangle) = S\,\frac{I}{a} = S\,\frac{A\,r^2}{a}.$$

which, solved with respect to S, gives the stress due to the bending moment of the load, alone

$$S = p\,\frac{(v + \triangle)\,a}{r^2}.$$

Adding this to the direct compressive stress p, we get

$$F = p + S = p\left[1 + \frac{a}{r^2}\,(v + \triangle)\right] = p\left[1 + \frac{a}{r^2}\,v\sec\left(\sqrt{\frac{p}{E}}\,\frac{l}{r}\right)\right] \quad (9.)^*$$

In general, this formula may be used for finding the maximum compressive stress produced on an eccentrically loaded column, the eccentricity of the load being *v*, and the load itself, *p lbs.* per square inch of the cross-section of the column. At present we will, however, only make use of it to determine, as we have set out to do, the proper working load to be used on a centrally loaded column. We therefore substitute in it the value of v in (7), and thus get

$$F = p\left\{1 + \left[n_c - 1 + 4\frac{n_1}{\pi^2}\cos\left(\frac{\pi}{2\sqrt{n_1}}\right)\frac{F}{E}\left(\frac{l}{r}\right)^2\right]\sec\left(\sqrt{\frac{p}{E}}\,\frac{l}{r}\right)\right\} \quad (10.)$$

Here, then, is a purely rational formula for the proper working load on a column fixed at one end and free to turn and to move laterally at the other, which, so far as its theory goes, apparently leaves nothing to be desired. As, however, it can be solved tentatively only, with respect to p, it can be of no practical value, and we shall accordingly have to *so* simplify it by the substitution of suitable approximations for some of its elements that it will be sufficiently convenient for practical use.

This formula is peculiar in that it contains two distinct factors of safety of entirely different natures—viz., n_c on the elastic limit F of the crushing resistance of the material, such that $\frac{F}{n_c} = f$ is a proper working load on the material under direct compression only; and n_1 on Euler's load for a column so long that the direct crushing tendency may be entirely neglected as compared with the bending tendency.† But while the first of these factors will no doubt

*The writer has recently learned that this formula has also been derived by Prof. A. Marston, of the Iowa State College.

†The former might be called a factor of safety as to the materials used, and the latter a factor of safety as to the maximum loads.—J. B. J.

have to be varied with the material and particular circumstances of the cases, there seems to be no reason why a permanent value should not be adopted for n_1, and this thereby made to *apparently* disappear from the formula.

We have already concluded that a very moderate value of n_1 ought to be sufficient, but in order not to be too radical in suggesting greater working loads for long columns than have heretofore been considered safe, and on account of the simplification it introduces, we will adopt $\frac{9}{4}$ as a suitable value. Formula (10) then reduces to

$$F = p\left\{1 + \left[n_c - 1 + \frac{45}{\pi^2}\frac{F}{E}\left(\frac{l}{r}\right)^2\right]\sec\left(\sqrt{\frac{p}{E}}\,\frac{l}{r}\right)\right\}, \quad (11.)$$

as $\cos\left(\frac{\pi}{2\sqrt{n_1}}\right)$ then becomes $\cos\left(\frac{2}{3}\times\frac{\pi}{2}\right) = \cos 60^\circ = \frac{1}{2}$.

Making likewise $n_1 = \frac{9}{4}$ in (5) we get $v_1 + \triangle_1 = v_1 \sec 60^\circ = 2\,v_1$, or $\triangle_1 = v_1$, so that by thus adopting $n_1 = \frac{9}{4}$ we insure that the deflection of an otherwise perfect column of finite length can never quite reach an amount equal to any possible actual eccentricity of the load.

Before proceeding to further simplify formula (11), as suggested above, we will try to more fully realize its significance by a study of the diagram, Fig. 4, in which are represented simultaneous values of v, $\triangle$, and p, for various values of $\frac{l}{r}$ from 0 to 300, for a material whose elastic limit in compression is $F = 34{,}000$ pounds, and whose modulus of elasticity is $E = 27{,}000{,}000$ pounds, and for a value of the factor of safety n_c equal to 4.

Distances up the vertical line in the middle of the diagram represent $\frac{l}{r}$ *; the horizontal distances from this line over to the heavy curve to the left represent the corresponding values of p, as derived from (11); the horizontal distances over to the first heavy curve to the right represent the corresponding values of v, as figured by (7) for $n_1 = \frac{9}{4}$; and the horizontal distances over to the second heavy curve to the right represent the corresponding values of $(v + \triangle)$, as figured by (8) for $n_1 = \frac{9}{4}$.

Considering thus, for instance, a column for which $\frac{l}{r} = 200$, or $\frac{l}{r} = 400$ for both ends pivoted, we find $p = 685.1$ pounds, $v = 25.97\,\frac{r^2}{a}$, and $v + \triangle = 48.63\,\frac{r^2}{a}$.

This means, accordingly, that the total working load for this

*The reader must keep in mind that these values of $\frac{l}{r}$ are just one-half those for both ends pivoted.—J. B. J.

column would be 685.1 pounds $\times$ A, and that this, if given the initial eccentricity $25.97 \frac{r^2}{a}$, would produce a lateral deflection of the column which, together with the initial eccentricity, would amount to an effective leverage of the load equal to $48.63 \frac{r^2}{a}$, the bending moment of the load thus becoming $685.1 \times A \times 48.63 \frac{r^2}{a}$. This bending moment would produce a bending stress S, which, determined from the equation

$$685.1 \times A \times 48.63 \frac{r^2}{a} = S \frac{I}{a} = S \frac{A r^2}{a},$$

becomes S = 685.1 pounds $\times$ 48.63 = 33,316.4 pounds, and which, added to the direct compressive stress of 685.1 pounds, gives a total maximum stress of 34,001.5 pounds, or, as near as could be expected without more exact figuring, the elastic limit of 34,000 pounds, which was assumed.

We will now pass over to the simplification of formula 11, which is brought about by approximating cos x by $\left(1 - \frac{4.5}{\pi^2} x^2\right)$.

This approximation has been arrived at by considering Fig. 5, in which the one curve is a sinusoid, and the other curve is a parabola with the same vertex as this sinusoid, and intersecting it at the point whose ordinate is $\sin. \frac{\pi}{6} = \cos \frac{\pi}{3} = \frac{1}{2}$.

Now, by adopting $n_1 = \frac{9}{4}$, we have insured that the *angle* $\left(\sqrt{\frac{p}{E}} \frac{l}{r}\right)$ will never quite reach $\frac{\pi}{3}$, and we thus see that, for all possible values of this angle in (11), the parabola represents the sinusoid quite closely, with the maximum percentage of error occurring for an intermediate value of this angle, and with increasing accuracy towards its two limits, o and $\frac{\pi}{3}$.

We accordingly write, approximately,

$$\sec\left(\sqrt{\frac{p}{E}} \frac{l}{r}\right) = \frac{1}{\cos\left(\sqrt{\frac{p}{E}} \frac{l}{r}\right)} = \frac{1}{1 - \frac{4.5}{\pi^2} \frac{p}{E} \left(\frac{l}{r}\right)^2},$$

which, substituted in (11), gives

$$F = p\left[1 + \frac{n_e - 1 + \frac{4.5}{\pi^2} \frac{F}{E} \left(\frac{l}{r}\right)^2}{1 - \frac{4.5}{\pi^2} \frac{p}{E} \left(\frac{l}{r}\right)^2}\right].$$

This equation can be solved with respect to p, but leads to a rather elaborate formula. We therefore transform it as follows:

$$F\left[1-\frac{4.5}{\pi^2}\frac{p}{E}\left(\frac{l}{r}\right)^2\right]=p\left[1-\frac{4.5}{\pi^2}\frac{p}{E}\left(\frac{l}{r}\right)^2+n_c-1+\frac{4.5}{\pi^2}\frac{F}{E}\left(\frac{l}{r}\right)^2\right]$$

$$F-p\times\frac{4.5}{\pi^2}\frac{F}{E}\left(\frac{l}{r}\right)^2=p\left[n_c-\frac{p}{F}\times\frac{4.5}{\pi^2}\frac{F}{E}\left(\frac{l}{r}\right)^2+\frac{4.5}{\pi^2}\frac{F}{E}\left(\frac{l}{r}\right)^2\right]$$

$$F=p\left[n_c-\frac{1}{2}\frac{p}{F}\times\frac{9}{\pi^2}\frac{F}{E}\left(\frac{l}{r}\right)^2+\frac{9}{\pi^2}\frac{F}{E}\left(\frac{l}{r}\right)^2\right]$$

$$p=\frac{F}{n_c+\frac{9}{\pi^2}\frac{F}{E}\left(\frac{l}{r}\right)^2\left(1-\frac{1}{2}\frac{p}{F}\right)} \qquad (12.)$$

Considering now the expression $\frac{1}{2}\frac{p}{F}$ of this equation, we readily realize that its influence on the value of p must be greatest for some intermediate value of $\frac{l}{r}$, and that the same will decrease with $\frac{l}{r}$ approaching either of its limits 0 and ∞. But as $\frac{1}{2}\frac{p}{F}$ has its maximum value $\frac{1}{2}\frac{p}{n_c p}=\frac{1}{2n_c}$ for $\frac{l}{r}=0$, which will thus always be a comparatively small fraction, $\left(1-\frac{1}{2}\frac{p}{F}\right)$ will differ from 1 by a moderate percentage only, for that value of $\frac{l}{r}$ for which the difference will have the greatest influence on the value of p.

We may therefore, without a very large percentage of maximum error, approximately write

$$p=\frac{F}{n_c+\frac{9}{\pi^2}\frac{F}{E}\left(\frac{l}{r}\right)^2}. \qquad (13.)$$

Now, in deriving (12) from (11), the error introduced consisted in writing cos. $\left(\sqrt{\frac{p}{E}}\frac{l}{r}\right)$ greater than its true value; that is, sec. $\left(\sqrt{\frac{p}{E}}\frac{l}{r}\right)$ less than its true value, the result being that p figured from (12) will be somewhat too large. But p figured from (13) will be less than figured from (12), and the effect of substituting 1 for $\left(1-\frac{1}{2}\frac{p}{F}\right)$ is thus actually in the direction of compensating for the error introduced into (12).

It thus follows that (13) must give values of p that are close to the values given by (11), though the degree of agreement between the two formulas will depend on the value of n_c, and also somewhat on the ratio $\frac{F}{E}$. Thus, for small values of n_c, the effect of

neglecting $\frac{1}{2}\frac{p}{F}$ will be overcompensating, while for large values of n_c the effect will not be fully compensating.

Formula (13) may be further simplified by dividing both its numerator and denominator by n_c, bearing in mind that $\frac{F}{n_c} = f$ is the proper working stress of the material under a simple crushing load. We thus finally get

$$p = \frac{f}{1 + \frac{9}{\pi^2}\frac{f}{E}\left(\frac{l}{r}\right)^2} = \frac{f}{1 + .912\frac{f}{E}\left(\frac{l}{r}\right)^2} \qquad (14.)$$

This formula, though of the same form as the Rankine-Gordon, is nevertheless of an entirely different nature, as the latter purports to give the ultimate strength of a column, the very idea of which is here repudiated. Besides, the coefficient for $\left(\frac{l}{r}\right)^2$ in the Rankine-Gordon formula is merely empirical.

In the diagram, Fig. 4, the pressures marked at the extreme left have been figured by (14). The maximum discrepancy of these pressures, compared with those figured by 11, and represented by the heavy curve, occurs for $\frac{l}{r} = 60$, and amounts to only 2.2 per cent.

COMPARISON WITH PROF. JOHNSON'S PARABOLIC FORMULA.

The fine curve to the left in the diagram, Fig. 4, represents pressures figured by Professor Johnson's parabolic formula and Euler's formula, with a common factor of safety of 4. It will be seen that the pressures figured by the parabolic formula, as far as it goes, differ but little from those here recommended; and in so far as this formula represents good practice, it bears testimony to the soundness of the one here proposed. But it will also be noticed how rapidly the pressures figured by Euler's formula drop below those here proposed.

The two fine curves to the right represent, respectively, values of v and $(v + \triangle)$ corresponding to the pressures of the parabolic and Euler's formula, and clearly show the lack of continuity of these formulas considered as one, and also the unreasonably large allowance for eccentric displacement of the load for long columns, which the latter formula is equivalent to when used with a uniform factor of safety as high as 4.

ECCENTRICALLY-LOADED COLUMNS.

We will now see how formula (13) may be so modified as to also answer for a column whose load is intentionally eccentric.

Fig. 6, a, represents an exceedingly short column with its load $P_c = p_c A$ applied a distance w from the center, the maximum stress produced being $f = \frac{F}{n_c}$. Fig. 6, b, represents the same column with its load removed to such a greater distance v_c from the center that the maximum stress produced is increased to the full elastic limit F.

Proceeding as before, we may then write

$$f = \frac{F}{n_c} = p_c\left(1 + \frac{w\,a}{r^2}\right) \text{ and } F = p_c\left(1 + \frac{v_c\,a}{r^2}\right),$$

from which we get

$$\frac{F}{p_c} = n_c\left(1 + \frac{w\,a}{r^2}\right) = 1 + \frac{v_c\,a}{r^2}.$$

Solving this equation with respect to v_c, we then write

$$v_c = \left[n_c\left(1 + \frac{w\,a}{r^2}\right) - 1\right]\frac{r^2}{a} \quad (15.)$$

Comparing this with 1, we see that substituting v_c as given by (15), for v_c as given by 1, throughout our whole previous discussion, will simply lead to getting $n_c\left(1 + \frac{w\,a}{r^2}\right)$ instead of n_c in formula (13).

For an eccentrically-loaded column we accordingly write

$$p = \frac{F}{n_c\left(1 + \frac{w\,a}{r^2}\right) + \frac{9}{\pi^2}\frac{F}{E}\left(\frac{l}{r}\right)^2} = \frac{f}{1 + \frac{w\,a}{r^2} + \frac{9}{\pi^2}\frac{f}{E}\left(\frac{l}{r}\right)^2} =$$

$$\frac{f}{1 + \frac{w\,a}{r^2} + .912\,\frac{f}{E}\left(\frac{l}{r}\right)^2} \quad (16.)$$

COLUMNS SUBJECTED TO TRANSVERSE LOADS.

From formula 2 we get

$$v + \triangle = v \sec\left(\sqrt{\frac{p}{E}}\,\frac{l}{r}\right),$$

$$v\left[\sec\left(\sqrt{\frac{p}{E}}\,\frac{l}{r}\right) - 1\right] = v\left[\frac{1}{\cos\left(\sqrt{\frac{p}{E}}\,\frac{l}{r}\right)} - 1\right] =$$

$$v\,\frac{1 - \cos\left(\sqrt{\frac{p}{E}}\,\frac{l}{r}\right)}{\cos\left(\sqrt{\frac{p}{E}}\,\frac{l}{r}\right)} = \triangle;\ \text{or}\ v = \frac{\cos\left(\sqrt{\frac{p}{E}}\,\frac{l}{r}\right)}{1 - \cos\left(\sqrt{\frac{p}{E}}\,\frac{l}{r}\right)}\triangle.$$

For low values of $\sqrt{\frac{p}{E}}\,\frac{l}{r}$, $\cos.\left(\sqrt{\frac{p}{E}}\,\frac{l}{r}\right)$ may be approximated by $1 - \frac{1}{2}\frac{p}{E}\left(\frac{l}{r}\right)^2$, which, substituted above, gives

$$v = \frac{1 - \frac{1}{2}\,\frac{p}{E}\left(\frac{l}{r}\right)^2}{1 - \left[1 - \frac{1}{2}\,\frac{p}{E}\left(\frac{l}{r}\right)^2\right]} \triangle = \left[2\,\frac{E}{p}\left(\frac{r}{l}\right)^2 - 1\right] \triangle, \qquad (17.)$$

and

$$v + \triangle = 2\,\frac{E}{p}\left(\frac{r}{l}\right)^2 \triangle\,. \qquad (18.)$$

Denoting by S the total stress produced, instead of merely the bending stress, in formula (9.), we write this

$$S = p\left[1 + \frac{a}{r^2}(v + \triangle)\right].$$

Substituting herein the value of $(v + \triangle)$ in (18), we get

$$S = p\left[1 + \frac{a}{r^2} \times 2\,\frac{E}{p}\left(\frac{r}{l}\right)^2 \triangle\right] = p + 2\,\frac{a\,E}{l^2}\,\triangle,$$

which gives

$$p = S - 2\,\frac{a\,E}{l^2}\,\triangle \qquad (19.)$$

By means of this formula we can thus approximately determine that eccentric load on a column which will produce a certain maximum stress S and a certain deflection $\triangle$, and by formula (17.) we can subsequently determine its eccentricity.

In Fig. 7, a, is shown a column subjected to the transverse loads P_h at its extremity and L uniformly distributed over its length; and in Fig. 7, b, the same column is shown subjected to an eccentrically applied vertical load $P_v = p_v\,A$, which produces the same deflection $\triangle$ and the same maximum stress S as the transverse loads.

We have

$$(P_h + \tfrac{1}{2}\,L)\,l = S\,\frac{I}{a}\;;\text{ or } S = (P_h + \tfrac{1}{2}L)\,\frac{l\,a}{A\,r^2}, \qquad (20.)$$

and also the well-known formula for the deflection,

$$\triangle = (\tfrac{1}{3}\,P_h + \tfrac{1}{8}\,L)\,\frac{l^3}{E\,A\,r^2} \qquad (21.)$$

Substituting (20.) and (21.) in (19.) we get

$$p_v = (P_h + \tfrac{1}{2}\,L)\frac{l\,a}{A\,r^2} - 2\,\frac{a\,E}{l^2}\,(\tfrac{1}{3}\,P_h + \tfrac{1}{8}\,L)\frac{l^3}{E\,A\,r^2} = (\tfrac{1}{3}\,P_h + \tfrac{1}{4}\,L)\frac{l\,a}{A\,r^2} \qquad (22.)$$

which gives

$$P_v = (\tfrac{1}{3}\,P_h + \tfrac{1}{4}\,L)\,\frac{l\,a}{r^2} \qquad (23.)$$

Substituting, further, (21.) and (22.) in (17.), we get

$$v = \left[2\,\frac{E\,A\,r^2}{(\frac{1}{3}\,P_h + \frac{1}{4}\,L)\,l\,a}\left(\frac{r}{l}\right)^2 - 1\right](\tfrac{1}{3}\,P_h + \tfrac{1}{8}\,L)\,\frac{l^3}{E\,A\,r^2} \text{ or}$$

$$v = \frac{\frac{2}{3}\,P_h + \frac{1}{4}\,L}{\frac{1}{3}\,P_h + \frac{1}{4}\,L}\,\frac{r^2}{a} - (\tfrac{1}{3}\,P_h + \tfrac{1}{8}\,L)\,\frac{l}{E\,A}\left(\frac{l}{r}\right)^2. \qquad (24.)$$

Multiplying (23) by (24), we may also write

$$P_v\,v = (\tfrac{2}{3}\,P_h + \tfrac{1}{4}\,L)\,l\left[1 - (\tfrac{1}{6}\,P_h + \tfrac{1}{8}\,L)\,\frac{l}{E\,A}\left(\frac{l}{r}\right)^2\frac{a}{r^2}\right]. \quad (25.)$$

If now we have a column loaded as shown in Fig. 8, a, we may substitute a vertical load P_v applied at the distance v from the center of the column, for the transverse loads P_h and L, as indicated in Fig. 8, b. Combining this ideal vertical load P_v with the actual vertical load P we finally get the ideal vertical load P_w (Fig. 8, c), which will then be approximately equivalent in its effect to the three actual loads P_h, L, and P_v.

In order to determine the magnitudes of P_w and its eccentricity w, we first determine P_v and v by (20) and (21) respectively, and then write $P_w = P_v + P$, and $P_w\,w = P_v\,v + P\,u$, which gives

$$w = \frac{P_v\,v + P\,u}{P_v + P} \quad (26.)$$

Substiuting this value of w in (16), we finally ascertain whether $P_w = P_v + P$ constitutes a proper load or not.

For a horizontal column whose weight, W, is the only transverse load, and on which the end pressure is applied centrally, the above formulas become much simplified, for we then have $L = W$, $P_h = 0$ and $u = 0$.

Formula (23) thus reduces to

$$P_v = \tfrac{1}{4}\,W\,l\,\frac{a}{r^2}, \quad (27.)$$

(24) to

$$v = \frac{r^2}{a} - \frac{W\,l}{8\,E\,A}\left(\frac{l}{r}\right)^2. \quad (28.)$$

and (25) to

$$P_v\,v = \tfrac{1}{4}\,W\,l\left(1 - \frac{W\,l}{8\,E\,A}\left(\frac{l}{r}\right)^2\frac{a}{r^2}\right). \quad (29.)$$

Substituting (27) and (29) in (26), and remembering that $u = 0$, we get

$$w = \frac{\tfrac{1}{4}\,W\,l\left(1 - \frac{W\,l}{8\,E\,A}\left(\frac{l}{r}\right)^2\frac{a}{r^2}\right)}{\tfrac{1}{4}\,W\,l\,\frac{a}{r^2} + P} = \frac{\frac{r^2}{a} - \frac{W\,l}{8\,E\,A}\left(\frac{l}{r}\right)^2}{1 + \frac{4\,P}{W\,l}\,\frac{r^2}{a}} \quad (30.)$$

APPENDIX.

In order, now, to derive formula (2) we again refer to Fig. 2, and fall back upon the well-known differential equation

$$B\,M = E\,I\,\frac{d^2y}{dx^2},$$

in which B M is the bending moment for any section of a beam.

The elastic curve being here concave to the axis of abscissas, we have $\frac{d^2y}{dx^2}$ negative, and, as $B\,M = P\,(y + v)$, we write

$$P\,(y + v) = -\,E\,I\,\frac{d^2y}{dx^2}.$$

Multiplying both sides of this equation by dy, and dividing by E I, it becomes

$$\frac{P}{E\,I}\,(y + v)\,dy = -\,\frac{1}{dx^2}\,(dy \times d^2y).$$

Integrating both sides, and multiplying by 2, this gives

$$\frac{P}{E\,I}\,(y^2 + 2\,v\,y) = -\left(\frac{dy}{dx}\right)^2 + C.$$

But $\frac{dy}{dx} = 0$ for $y = \triangle$, and hence $C = \frac{P}{E\,I}\,(\triangle^2 + 2\,v\,\triangle)$, which substituted above gives

$$\left(\frac{dy}{dx}\right)^2 = \frac{P}{E\,I}\,(\triangle^2 + 2\,v\,\triangle - y^2 - 2\,v\,y), \text{ or}$$

$$\frac{dy}{\sqrt{\triangle^2 + 2\,v\,\triangle - y^2 - 2\,v\,y}} = \sqrt{\frac{P}{E\,I}}\;dx.$$

Integrating again gives

$$\sin^{-1}\frac{y + v}{\triangle + v} = \sqrt{\frac{P}{E\,I}}\;x + C^1.$$

But $y = \triangle$ for $x = l$, and hence

$$\sin^{-1}\frac{y + v}{y + v} = \sin^{-1} 1 = \frac{\pi}{2} = \sqrt{\frac{P}{E\,I}}\;l + C^1, \text{ or } C^1 = \frac{\pi}{2} - \sqrt{\frac{P}{E\,I}}\;l,$$

which, substituted above, gives

$$\sin^{-1}\frac{y + v}{\triangle + v} = \sqrt{\frac{P}{E\,I}}\;x + \frac{\pi}{2} - \sqrt{\frac{P}{E\,I}}\;l = \frac{\pi}{2} - \sqrt{\frac{P}{E\,I}}\;(l - x),$$

and from which it follows that

$$\cos^{-1}\frac{y + v}{\triangle + v} = \sqrt{\frac{P}{E\,I}}\;(l - x),$$

and further that

$$\frac{y + v}{\triangle + v} = \cos\left[\sqrt{\frac{P}{E\,I}}\;(l - x)\right], \text{ or}$$

$$y + v = (\triangle + v)\cos\left[\sqrt{\frac{P}{E\,I}}\;(l - x)\right]. \qquad (31.)$$

But $y = 0$ for $x = 0$, and hence

$$v = (\triangle + v)\cos\left(\sqrt{\frac{P}{E\,I}}\;l\right), \text{ or}$$

$$\triangle + v = v\sec\left(\sqrt{\frac{P}{E\,I}}\;l\right) = v\sec\left(\sqrt{\frac{P}{A\,E}}\;\frac{l}{r}\right) = v\sec\left(\sqrt{\frac{p}{E}}\;\frac{l}{r}\right) (2.)$$

Q. E. D.

Solving (2) with respect to v, this becomes

$$v = \frac{\triangle}{\sec\left(\sqrt{\frac{P}{EI}}\, l\right) - 1} = \triangle \frac{\cos\left(\sqrt{\frac{P}{EI}}\, l\right)}{1 - \cos\left(\sqrt{\frac{P}{EI}}\, l\right)}, \tag{32.}$$

which makes

$$\triangle + v = \frac{\triangle}{1 - \cos\left(\sqrt{\frac{P}{EI}}\, l\right)}. \tag{33.}$$

Substituting (32) and (33) in (31) we get

$$y = \triangle \times \frac{\cos\left[\sqrt{\frac{P}{EI}}\,(l - x)\right] - \cos\left(\sqrt{\frac{P}{EI}}\, l\right)}{1 - \cos\left(\sqrt{\frac{P}{EI}}\, l\right)}$$

$$= v \times \frac{\cos\left[\sqrt{\frac{P}{EI}}\,(l - x)\right] - \cos\left(\sqrt{\frac{P}{EI}}\, l\right)}{\cos\left(\sqrt{\frac{P}{EI}}\, l\right)}, \tag{34.}$$

which is thus the equation of the elastic curve, both in terms of the maximum deflection $\triangle$ and in terms of the initial eccentricity of the load.

By approximating cos x by $(1 - a\,x^2)$, as we did before, this equation reduces to $y = \frac{\triangle}{l^2}(2\,l\,x - x^2)$ (35.)

which is that of a parabola.

APPROXIMATE FORMULAS FOR ULTIMATE STRENGTH.

With greater or less accuracy, according as n_1 is taken greater or less than $\frac{9}{4}$, the general formula (10) may be simplified in the same manner as the special formula (11).

The general form of (12) thus derived is

$$p = \frac{F}{n_c + \frac{4\,n_1}{\pi^2}\,\frac{F}{E}\left\{1 - \left[1 - \cos\left(\frac{\pi}{2\sqrt{n_1}}\right)\right]\frac{p}{F}\right\}\left(\frac{l}{r}\right)^2}, \tag{20.}$$

which again leads to the general form of (13),

$$p = \frac{F}{n_c + \frac{4\,n_1}{\pi^2}\,\frac{F}{E}\left(\frac{l}{r}\right)^2} \tag{21.}$$

By the substitution of this last value of p in the denominator of (20), we may also write.

$$p = \frac{F}{n_c + \frac{4\,n_1}{\pi^2}\,\frac{F}{E}\left(\frac{l}{r}\right)^2 - \frac{\left(1 - \cos\frac{\pi}{2\sqrt{n_1}}\right)\frac{4\,n_1}{\pi^2}\,\frac{F}{E}\left(\frac{l}{r}\right)^2}{n_c + \frac{4\,n_1}{\pi^2}\,\frac{F}{E}\left(\frac{l}{r}\right)^2}} \tag{22.}$$

which, for low values of n_c, will be more nearly correct than either (20), whose values are too high, or (21), whose values are too low.

If we put $n_c = n_l = 1$, in formulas (21) and (22), we get

$$p_u = \frac{F}{1 + \frac{4}{\pi^2}\frac{F}{E}\left(\frac{l}{r}\right)^2} \qquad (23.)$$

and

$$p_u = \frac{F}{1 + \frac{4}{\pi^2}\frac{F}{E}\left(\frac{l}{r}\right)^2 - \frac{\frac{4}{\pi^2}\frac{F}{E}\left(\frac{l}{r}\right)^2}{1 + \frac{4}{\pi^2}\frac{F}{E}\left(\frac{l}{r}\right)^2}}, \qquad (24.)$$

which may then be considered as approximate formulas for ultimate loads.

In so far as we started out on the assumption that there could be no truly rational formula for the ultimate strength of a column, these formulas are somewhat enigmatic; but a little reflection makes it evident that they owe their birth to the error introduced by our method of approximating formula (10), which itself becomes $F = p$ when we put $n_c = n_l = 1$.

The fact is that, when we make $n_c = 1$ in formula (10), we thereby make $v_c = 0$ for all values of $\frac{l}{r}$, while, on account of the error introduced by our approximations, v_c does not become 0 when we make $n_c = 1$ in formulas (21) and (22), except for $\frac{l}{r} = 0$ and ∞.

Substituting values of p_u, determined by either of these formulas, for p in formula (9), and then solving for v, we can determine the eccentricities that these loads p_u must be given in order to produce the stress F, and thus become destructive. Doing this, and plotting the simultaneous values of $\frac{l}{r}$, p_u and v, as done in the diagram, Fig. 9, we get a clear idea of what these formulas really mean.

To facilitate the necessary calculations, the values of $\frac{l}{r}$ selected have been made multiples of that value of this ratio, for which Euler's load p_e (formula 3) is just equal to the elastic limit F of the material.

This is readily found to be

$$\frac{l'}{r} = \frac{\pi}{2}\sqrt{\frac{E}{F}}$$

Writing, then,

$$\frac{l}{r} = x\frac{l'}{r} = x\frac{\pi}{2}\sqrt{\frac{E}{F}}.$$

and substituting this in (9), we get

$$F = p\left[1 + \frac{a}{r^2}\, v \sec\left(\sqrt{\frac{p}{E}}\; x\; \frac{\pi}{2}\; \sqrt{\frac{E}{F}}\right)\right] =$$

$$p\left[1 + \frac{a}{r^2}\, v \sec\left(x\; \frac{\pi}{2} \sqrt{\frac{p}{F}}\right)\right],$$

which, solved for v, gives

$$v = \left(\frac{F}{p} - 1\right) \cos\left(x\; \frac{\pi}{2} \sqrt{\frac{p}{F}}\right)\; \frac{r^2}{a}\,.$$

Euler's, and Professor Johnson's parabolic formula have also been plotted in the diagram, together with the eccentricities corresponding to the loads given by the latter.

The curve to the extreme left is the locus of Euler's formula, and the short, heavy curve, that of the parabolic formula, which is

$$p = F\left[1 - \frac{1}{\pi^2}\,\frac{F}{E}\left(\frac{l}{r}\right)^2\right],$$

and which gives the same load as the former formula for

$$\frac{l}{r} = 1\;\;2\;\; \frac{\pi}{2}\sqrt{\frac{E}{F}} = 1\;\;2\;\; \frac{l'}{r}\;;\ \text{viz.}\ p = \tfrac{1}{2}\,F,$$

so that this is the maximum value of the ratio $\frac{l}{r}$ for which this formula is intended to be applied.

The second curve to the left is the locus of formula (22), while the third is that of formula (21).

The first short curve to the right is the locus of the eccentricity involved in the parabolic formula; the second curve to the right is the locus of the eccentricity involved in formula (22), and the last curve is the locus of the eccentricity involved in formula (21). The maximum eccentricity involved in the parabolic formula is about .076 $\frac{r^2}{a}$, and occurs for about

$$\frac{l}{r} = 1\;\; \frac{4}{4}\;\; \frac{l'}{r}\;;$$

the maximum of that involved in formula (22) is about .157 $\frac{r^2}{a}$, and occurs for about

$$\frac{l}{r} = 1\;\; \frac{3}{2}\;\; \frac{l'}{r}\;;$$

while that of (21) increases steadily towards $\frac{r^2}{a}$ as $\frac{l}{r}$ increases towards ∞.

From the close agreement between all the formulas, for great values of $\frac{l}{r}$, we see that a little more or less eccentricity of the load is of no material consequence for a very long column, which

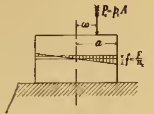
FIG. 1, a

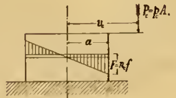
FIG. 1, b

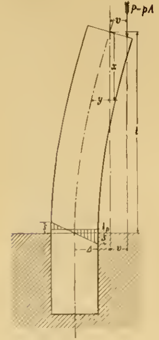
FIG. 2


FIG. 3

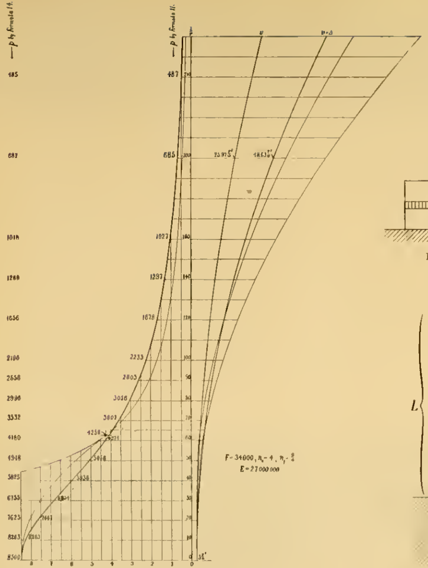
FIG. 4

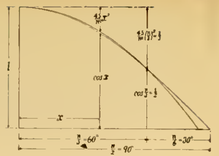
FIG. 5.

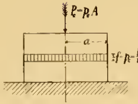
FIG. 6, a.

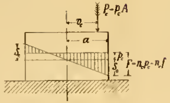
FIG. 6, b

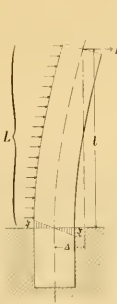
FIG. 7, a.


FIG. 7, b.

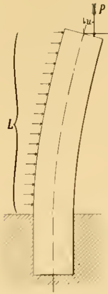
FIG. 8, a.


FIG. 8, b.

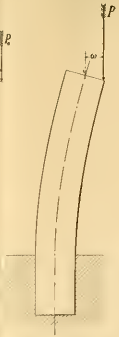
FIG. 8, c

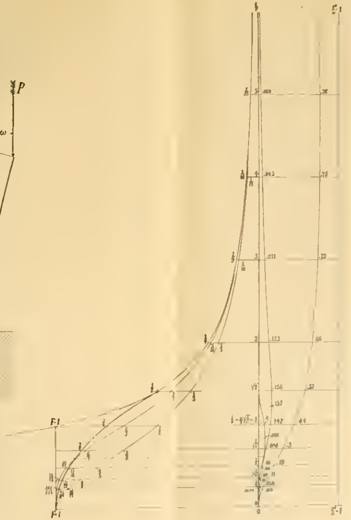
FIG. 9.

fact is an additional evidence of the sufficiency of only a low factor of safety on the destructive loads of such columns.

If an exceedingly short column is given an eccentricity equal to the maximum involved in the parabolic formula its destructive load will be $\frac{F}{1 + .076} = .929$ F; if given the maximum involved in formula (22) this load will be $\frac{F}{1 + .157} = .864$ F, and if given the maximum involved in (21) it will be $\frac{F}{1 + 1} = .5$ F.

For that value of $\frac{l}{r}$ for which the eccentricity involved in formula (22) is a maximum, that of formula (21) is about $\frac{1}{2}\frac{r^2}{a}$; and if an exceedingly short column is given this eccentricity its destructive load will become $\frac{F}{1 + \frac{1}{2}} = \frac{2}{3}$ F.

We thus see that the eccentricities involved in formula (21) are so unreasonably large—except for exceedingly short columns—that this formula cannot lay any claim to give even a rough approximation to the *ultimate* load of anything but either an exceedingly long or an exceedingly short column; and as this formula is really the Rankine-Gordon formula, with a theoretical evaluation of the constant coefficient for $\left(\frac{l}{r}\right)^2$, the defectiveness of this formula seems thus pretty well established.

Even the eccentricities involved in formula (22) are excessive for just such values of $\frac{l}{r}$ as are mostly used in practice, but as it is not likely that a simple algebraic formula can be constructed that will involve smaller and more nearly uniform eccentricities, and at the same time be applicable to all values of $\frac{l}{r}$, it is hereby submitted as at least a great improvement on the Rankine-Gordon formula.

The more moderate, and for a comparatively longer stretch more nearly uniform eccentricities involved in Professor Johnson's parabolic formula, show, however, that this, though of a merely semi-theoretical origin, can claim to give better approximations to theoretically reasonable ultimate loads than even formula (22), for those values of $\frac{l}{r}$ to which it is necessarily restricted.

However, as a result of this investigation, the writer cannot help entertaining the opinion that nothing is gained by trying to determine the *ultimate* strength of a column, either by theory or by actual test, as in the light of what has been found, this will be of no use in determining a proper working load.

In concluding, it may be well to mention that the writer personally considers the value $\frac{9}{4}$ adopted for n_c in deducing formula (14) as unnecessarily large, and that this formula may quite safely be written

$$p = \frac{f}{1 + .6 \frac{f}{E} \left(\frac{l}{r} \right)^2},$$

which corresponds to a value of n_1 but little over 1.2. This still restricts $\Delta + v$ to less than $4 v$.

Formula (16) would then also become

$$p = \frac{f}{1 + \frac{a w}{r^2} + .6 \frac{f}{E} \left(\frac{l}{r} \right)^2}.$$

SOME INSTANCES OF PILES AND PILE-DRIVING, NEW AND OLD.

By Horace J. Howe, Member Boston Society of Civil Engineers.

[Read before the Society, March 30, 1898.*]

About two centuries ago, that all-around man of science and architect, Sir Christopher Wren, said to the Royal Society:

"For the improvement of *theories* we need to be least solicitous; it is a work which will insensibly grow on us, if we be always doing something in *experiment;* and every one is more prone to exercise his fancy in building paper theories than patient first to pile the unsure foundation and hew solid materials out of the history of nature. This is rather our task, and we must be content to plant crab stocks for posterity to graft on; and, instead of the vanity of prognosticating, I could wish we would have the patience for some years of *registering past times,* which is the certain way of learning to prognosticate; experiment and reason is the only way of prophesying natural events; in combating prejudices, detecting error, and establishing truth."

It is the aim of this paper to present facts rather than theories, and to give the experiments themselves rather than a discussion of the formulæ which have somehow managed to cluster around them.

In 1879 I made my first attempts, in company with a fellow student, F. B. Knapp (M. Bost. Soc.). The experiments were made on a small scale, and deserve mention only from the generally unsatisfactory nature of the results and from our perhaps hasty conclusion that the simplest formula was liable to be the best.

Since that time I have held official relations with not a few piles of larger growth in various parts of the country. The fact of having made some tests within the last year for the Boston Transit Commission, near Haymarket Square, under direction of H. A. Carson, Chief Engineer, was the immediate cause of this paper.

On account of the upward pressure of the tide-water upon the submerged station areas of the subway as designed at that time, this pressure being transferred by means of the concrete invert to the coned pile-heads, it was desirable to know something of the safe upward force, as well as the safe downward force, that could be applied to a pile. Sixteen spruce piles were driven $2\frac{1}{2}$ feet centers in a pit about 24 feet deep, penetrating into the clay from 11 to 34 feet, the successive sets and falls for every 10 blows being taken.

*Manuscript received February 26, 1898.—Secretary, Ass'n of Eng. Socs.

The Cavanaugh Extension-Rail Pile-Driver was used with 1710-pound hammer. Speaking generally, we got about ½ inch set for 11 feet drop, or 18,800 feet pounds, without deduction for overhaul of rope.

The effect of a rest over Sunday was shown by giving the piles 5 blows Monday morning and observing the set. The average was then compared with the average of the 10 taken previously. This is perhaps not so satisfactory as a single blow in each case would have been. The effect of rest is particularly noticeable in the case of piles when driven with bark on, the bark apparently easing the pile as it went down, owing, perhaps, to the lubricating

PLAN SHOWING ORDER IN WHICH PILES WERE DRIVEN.

Piles spaced 2 ft. 6 ins. between centers.
Nos. 1, 9, 10, 13, 14, 15, bark on.
Nos. 2 to 8, 11, 12 and 16, bark off.

action of water following down with greater freedom, or to the sliding of the pile inside the bark.

The successive sets for each 10 blows for each pile were plotted and show clearly that in the case of some piles the work of the hammer was to push away the material ahead of the point rather than to overcome the friction of the sides. The increase of this side friction over Sunday confirms this view.

So far as our knowledge of the locality goes, the clay gets no softer at the greater depths.

Grade of surface, E. 118.0.

Grade final cut-off or soft clay, E. 93.79.

Grade hard blue clay about 120 pounds per cubic foot, E. 90.

All piles cut off square on point.

Earth around piles rose about 6 inches during the driving.

No brooming of heads occurred.*

The piles were sawed off $2\frac{1}{2}$ feet above final cut-off. An I-beam 15 feet long was then arranged as a lever, pivoted on a pair of angles riveted together, with loose plates to adjust the height underneath, then fastened down to the adjoining pile by $\frac{7}{8}$-inch wire rope with two loops spliced, and loaded at the free end with about 6 tons of steel shapes, handy by. An upward pull of 10 or 12 tons was first tried on piles 3, 16, 14 and 2. Failing to start either one of these, we proceeded as indicated in the table. Nos. 4 and 5, 6 and 15, 9 and 12 were tested together in pairs. The only pile which moved of the six was No. 6, which had only 11 feet penetration, the top 4 feet being in softer clay. It settled 1.4 inches under a load of 38 tons and stopped. Estimated skin friction 3500 pounds per square foot in hard clay. No further settlement was observed for three hours, pile 15 meanwhile withstanding an upward pull of 31 tons with 16 feet penetration.

The test on piles 9 and 12 failed on account of pulling off the head of No. 12.

It is to be regretted that the test on Nos. 4 and 5 could not have been carried to the ultimate load, which would have been 50 or 60 tons, in my judgment,—not an easy load to handle.

The purpose of the test, however, had been accomplished. Tests finished June 7, 1897. Mr. H. R. Kimball, Assistant Engineer.

In applying any formula dependent upon the set of pile, due to a certain fall of hammer, a correction for overhaul of line from drum to hammer should be made of from 8 to 10 per cent. upwards, this correction being subtracted from the weight of the hammer.

I have observed instances elsewhere where the engine was at some distance and working diagonally to the driver, with ropes, leaders, etc., new, where this correction averaged 50 per cent. for 10 cuts of the hammer line, using successive sets as a basis for comparison.

Of course, tests on single piles should be taken for what they are worth. It does not follow that a cluster would be of equal efficiency, on the average, to the results shown.

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*See experiments by Don J. Whittemore, American Society Civil Engineers, 1880.

PILE TESTS, BOSTON TRANSIT COMMISSION, NEAR HAYMARKET SQUARE.

								After Piles had been in Ground 36 Hrs.					REMARKS.		Lever Tests.		
Pile No.	Length, Feet.	Diameter Butt, Inches.	Diameter Point, Inches.	El. of Pt. before Driving, Feet. City Base.	Fall, Last Ten Blows, Feet.	Set, Last Ten Blows, Inches.	Average Set, Inches.	Fall, Five Blows, Feet.	Set, Five Blows, Inches.	Average Set, Inches.	El. of Pt. after Driving, Feet. City Base.	Penetration, Feet.			Up Tons.	Down Tons.	
1	41.5	11½	6	93.5	9	7	0.7	11	3	0.6	65.9	27.6	Driven 12.9 ft. May 21, 1897, 10.30 a. m. Continued May 22, 8.30 a. m.	Bark on.			
2	32.0	12	8	94.0	13	4	0.4	"	Not Taken	——	66.9	27.1	Driven May 21, 11 a. m.	Bark off.			
3	41.0	12	6	93.6	8	5	0.5	"	2	0.4	59.9	33.7	May 21, 1 p. m.	"			
4	38.6	12	7	93.7	8	4	0.4	"	1⅞	0.38	62.6	31.1	Began 4.30 p. m. May 21. Continued 7 a. m. May 22.	"	30.6		No movement of this Pile or of No. 5 from same loading.
5	35.0	12	7½	94.0	11	5	0.5	"	1 Blow=0.50		64.4	29.6	Began 7.30 a. m. May 22.	"		36.8	
6	30.0	12	8	93.4	10	7	0.7	"	3½	0.7	82.3	11.1	" 10 a. m. May 22.	"		38.0	Settled 1.4. (See No. 15.)
7	30.0	11	9	93.5	9	5	0.5	"	3	0.6	81.0	12.5	" 11 a. m. May 22.	"			
8	25.0	12	8½	93.8	9	5½	0.55	"	2⅝	0.53	78.8	15.0	" 1 p. m. May 22.	"			
9	25.0	12	8½	94.0	12	11	1.10	"	1¾	0.35	76.1	17.9	" 2 p. m. May 22.	Bark on.		31.0	At this strain Pile head No. 12 pulled off. Same loading.
10	25.0	12	8	94.0	12	9½	0.95	"	2⅛	0.43	76.8	17.2	" 3 p. m. May 22.	"			
11	25.0	11	7	93.9	9	5½	0.55	"	2⅝	0.53	76.9	17.0	" 4 p. m. May 22.	Bark off.			
12	25.0	12	8	94.0	10½	4	0.4	"	1	0.2	76.3	17.7	" 7 a. m. May 24	"	25.0		At this strain Pile head pulled off. (See No. 9.)
13	25.2	12	8½	94.2	10	5	0.5	"	2⅜	0.48	77.7	16.5	" 8 a. m. May 24.	Bark on.			
14	25.7	12	9	94.1	11½	6½	0.65	"	2¾	0.55	74.5	19.6	" 9 a. m. May 24.	"			
15	25.0	12	9½	94.1	8	4	0.4	"	1½	0.30	78.2	15.9	" 9.30 a. m. May 24.	"	31.0		No movement of this Pile, but No. 6 settled from same loading.
16	25.0	12	10½	94.3	11	6	0.6	"	2¼	0.45	74.8	19.5	" 10.15 a. m. May 24.	Bark off			

The history of piles and pile-driving is interesting and instructive. If we do not consider what has been done in the past, as suggested by Sir Christopher in the text, it might well be said of us:

> "The pile by the river's brim
> A wooden pile was to him,
> And it was nothing more."

To this end I beg leave to call your attention to the following authorities as I consider them:

SIR CHRISTOPHER WREN.

First, Sir Christopher himself is quoted (Davy, 1841) as saying that the piling when properly employed will outlast the durability of the superstructure itself. And he built St. Paul's and fifty churches besides.

PERRONET.

Coming down to the 18th century, the noted French constructor, Perronet, gives definite instructions regarding pile-driving. He said that a pile can support a load of 25 tons as soon as it refuses to move more than $\frac{3}{8}$ inch under 30 blows of a monkey weighing 1190 pounds falling 4 feet, or under 10 blows of the same monkey falling 12 feet. At Neuilly, however, Perronet placed a load of 51 tons on piles 13 inches square, but driving the pile till it refused to move more than 3-16 inch under 25 blows of a monkey of same weight falling $4\frac{1}{2}$ feet; but such a load was unusual.

At Bordeaux the driving was stopped when the pile did not go down more than 3-16 inch under 10 blows of a monkey weighing 1100 pounds falling about 15 feet. But one of the piers *settled considerably*, the load on a pile being 22 tons, whereas, at Rouen, by insisting on Perronet's rule, no settlement occurred.

In this connection it is stated that M. Sazilly concluded from experiments made at the Orleans Viaduct that piles might support, with security, a load of 40 tons when they refuse to move more than $\frac{1}{3}$ inch under 10 blows of a monkey weighing 1500 pounds falling 13 feet.

While these results seem large, it is to be noticed that the piles were 13 inches square, as stated.

LONDON BRIDGES.

A word here as to the London bridges, so instructive on account of their failures. In general, trouble came when piles fell short of reaching stiff blue clay and were too heavily loaded.

Old London Bridge was commenced in 1176 and finished about 1209. The piers rested on piles driven only around the outside of the pier, so placed as to carry the whole weight. They were of elm, and at the expiration of 600 years, on being drawn up, showed no material decay. A part of this bridge fell about 1281, and the whole structure was removed to give place to the new bridge in 1825. This gives us a clue to the age of the game we see the children play, familiar to all: "London Bridge is falling down," etc.

Old Westminster Bridge (1738-49) failed,—piles in one pier only.

Black Friar's Bridge (1760-71) failed also,—45 piles in each caisson. Rebuilt and completed 1869.

Waterloo Bridge (1809-17) failed,—68 tons per pile.

New London Bridge (1825-1831) has settled about a foot down stream in places,—80 tons per pile, or 5 tons per square foot of entire area of the pier.

New Westminster Bridge, begun in 1858, on the contrary, has not settled with 12 tons per pile (test of 60 tons) and 2 tons per square foot of foundation. Elm piles 32 feet long are driven 18 to 20 feet into the blue London clay.

New Tower Bridge, completed 1894,—caissons about 21 feet into the bed of the river.

PRACTICE IN HOLLAND.

Turning to Holland, we find the engineers using the following formula (Mason's) at the beginning of this century:

$$L = F \frac{W^2 h}{S (W + P)}$$

and also another modification similar to Sanders's formula.

In Holland the greater part of important engineering structures have to be built on piles which never reach rock; at the best, only a stratum of coarse sand or gravel, and often not even this, in which case the pile is supported by the friction and adhesion of the surrounding soil. R. Haagsma (*Engineering*, 1892) also states that the factor 6 was applied to the above formula generally. He proposes a new one, which he claims is more correct in theory:

$$L = F \frac{h_1 - h_2}{S_1 - S_2} \cdot \frac{W^2}{(W + P)}$$

Where h = fall.

W = weight of hammer.

P = weight of pile.

S = set.

L = safe load.

F = factor of safety.

Certainly the Dutch have had a long experience with bearing piles. The original site of the city of Amsterdam was a salt marsh requiring piles 50 to 60 feet long. After passing through a mixture of peat and sand of little consistency, at a depth of about 40 feet they enter a bed of firm clay. The tops are sawed level and covered with thick plank, on which the masonry is constructed. Though some of the houses have declined from the perpendicular, they are considered to be quite secure against falling.

The Palace was built in 1648. The natural ground is below the level of the ocean.

St. Petersburg is also founded on piles,—sometimes several tiers of them. Venice also. But data is wanting regarding both cities.

PRESERVATION UNDER WATER.

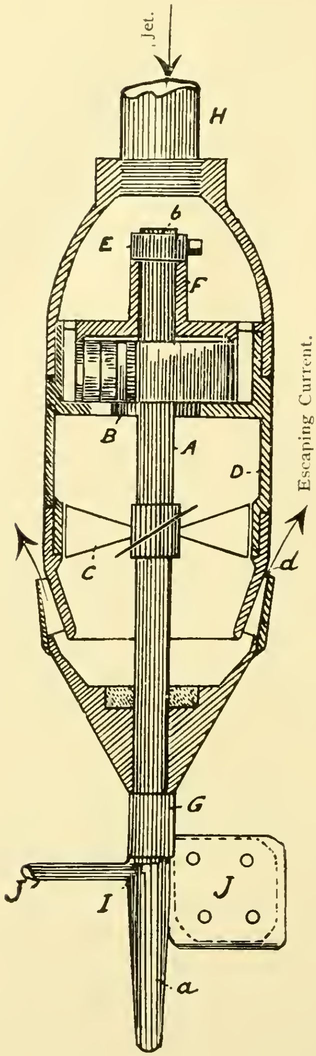
Before leaving the continent, however, mention might be made of a remarkable example of preservation of piles under water, in the bridge built by the Roman Emperor Trajan, over the Danube. Cresy ("Encyclopædia of Civil Engineering") states that a pile examined in the last century "was found petrified. This, however, was not the case for more than the thickness of $\frac{3}{4}$ inch, beyond which the timber was not in any way changed from its ordinary character." That is during 17 centuries.

ROYAL BORDER BRIDGE.

We come next to the Royal Border Bridge over the Tweed, formally opened by the Queen and Prince Albert, 1850, when Her Majesty was pleased to name it. Mr. Geo. B. Bruce, Chief Engineer, says in a paper to the Institution of Civil Engineers:

"It is very difficult to lay down any general laws with regard to piling. The strata through which a pile has to pass may in one case offer little resistance; yet other strata bearing the same name and apparently of the same character will offer great resistance and be very difficult to penetrate. Thus, though borings are exceedingly valuable, and afford great satisfaction to the engineer, inasmuch as he feels he is not working altogether in the dark, yet they cannot always be depended upon. Nothing can make him feel quite sure but actual trial, by driving a long pile as far as it can be got into the site of the pier.

"It is the common practice, when laying down in design the lengths of the piles, for carrying a bridge or other work, to show them to be driven 3 or 4 feet into gravel, provided it is conveniently situated; but, according to the experience gained in this



BORING MACHINE. (See p. 293.)

A. Shaft.
B. Turbine.
C. Propellor.
D. Casing.
H. Pipe from pump.
I. Two-blade propellor, or cutter.
J. Detachable steel plates.

work with Nasmyth's piling machine, even strong gravel does not present any great resistance to the motion of piles pitched 3 or 4 feet from each other, unless the gravel is lying on a *sub-stratum harder than itself*.

"Thus in some instances piles were driven down 30 feet below the bed of the river, and in strong gravel went at the rate of 1 inch by 3 blows, the strata under the gravel being soft; whereas when the gravel was on rock they did not penetrate more than 1 inch by 200 blows. The bearing-piles of this bridge carry each about 70 tons. The standard of intensity which was fixed for the driving of these piles was 1 inch by 150 blows at the end of the driving; but in two of the piers the driving did not average more than 1 inch by 20 blows of 1700-pound hammer falling 16 feet.

"This, though practice has proved it to be sufficient, is considered too easy [!] driving to be trusted with such a load, if circumstances admit of their being driven harder. They were driven from 30 to 40 feet into gravel and sand, which latter was in some cases wet.

"The greatest length of bearing-piles driven in one day of 10 hours was 189 feet; but the average driving was not more than 50 feet, making the average cost of manual labor 7½ pence per lineal foot. Total cost Royal Border Bridge, £120,000; composed of 28 semicircular arches, 61 feet 6 inches span; height above river, maximum, 126 feet."

JOHN C. TRAUTWINE.

John C. Trautwine *(Journal Franklin Institute*, 1842) gives various results and designs and argues in favor of piles for what he calls "railroad superstructure."

The Nasmyth steam hammer was invented in 1839, and first used in harbor works, 1845. This seems to have given an impetus to pile-driving in England and in this country.

COL. J. L. MASON—FORT MONTGOMERY, N. Y.

Next is Brevet Lieutenant-Colonel J. L. Mason's memoir on work at Fort Montgomery, Lake Champlain, dated 1850:

"Fort Montgomery is founded on a timber platform resting on 4383 piles driven into the ground. These piles were driven in 1844-46, and the grillage laid on them in those years and in 1848. These piles, when the work is completed, will bear an average load of 7 cubic yards of masonry and 1¾ cubic yards of earth; or, esti-

mating the masonry at 4200 pounds and the earth at 2700 pounds per cubic yard, the weight with which each pile will be loaded will amount to 34,125 pounds in addition to its own weight and that of the grillage.

"These piles were all driven by two steam engines, one of 6 horse, and the other of 8 horse-power, the former requiring generally an engineer and three laborers to serve it, and the latter an engineer and four laborers. The original cost of engines was $4388.71; the consumption of oil and rope, together with the repairs applied to them has amounted to $1982.21; total, $6370.92. I suppose they could now be sold for $1000 [not more than what they would cost to-day new], a sum not over one-third their value as pile-drivers if they were further needed at this work for that purpose. Deduct the $1000 and it leaves the amount actually bestowed on the pile-driving, $5370.92.

"The following is the itemized cost:

			Per Pile.
Machinery for 4383 piles	$5,370.92	or	$1.22
Cost of piles	6,121.42	"	1.40
Driving	1,724.44	"	.40
Measuring, hauling, securing for winter and sharpening	792.24	"	.18
Iron bands to protect the head while driving	439.29	"	.10
Cutting down and leveling the piles with axe and adze to receive grillage	495.21	"	.11
Machinery other than steam pile-drivers	184.10	"	.04
Contingent services and contingencies for this part of the work	1,890.05	"	.43
	$17,017.67		$3.88

"The general arrangement of the piles aimed at was to place their centers under the four angles of a square yard, the double pile-driver having been so constructed as to drive two rows two yards apart, from center to center, and on repassing the same track to insert an intermediate one, together with one outside the two already driven; but the distance from pile to pile in each row, resulting generally from dividing a given length into a certain number of spaces, would vary an inch or two from 3 feet.

The grillage was laid in two courses. The lower, of timber 15 inches wide and 12 inches thick, was generally laid perpendicular to the scarp, thus connecting together rows of piles parallel to the scarp. It was notched down 4 inches onto the piles and pinned. The upper course, at right angles to the lower, was of 12x12-inch

timber, across the piles, and of 12x8 inches between them, the 12x12-inch being notched 4 inches down on the lower course, brought its top to the same level as the 12x8-inch, thus giving a level floor with the masonry.

"The materials for the grillage, consisting of 45,610 running feet of timber of the sizes 12x8 inches, 12x12 inches and 12x15 inches, and of 12,147 hardwood pins, cost $2277.45; measuring, hauling and securing this timber for the winter, $235.80; preparing, laying and pinning, $2318.02; machinery, $70.00; contingent services and contingencies belonging to this part of the work, $612.66. Total cost of grillage, $5513.93. The difference of level between the highest and lowest water in this part of Lake Champlain is nearly 8 feet; according to our memorandum, 7 feet 10 inches.

"To prevent the decay of the wood it was necessary to place the top of the grillage at least as low as the lowest level of the surface of the water; the piles had to be accurately leveled 1 foot 4 inches below the top of the grillage. It thus became necessary, let the stage of water be what it would, to enclose the area with a cofferdam and dyke, and to pump out the water.

The cost of the coffer-dam and dyke, together 1700 feet long and enclosing an area of 2¾ acres was	$1,395.93
Pumping	1,504.21
Excavating for platform for the piles and grillage	1,587.87
Contingent services and contingencies belonging to these last three items	561.00
Total cost	$5,049.01

"We have then

For excavating, pumping and cofferdam	$5,049.01
Grillage	5,513.93
Piles	17,017.67
	$27,580.61

"Then follows the theoretical deduction of the formula already mentioned,

$$L = F \frac{W^2h}{S\,(W + P)}$$

"The hammer with which these piles were driven weighed 1630 pounds. The weight of the spruce piles was found to be 39 3-5

pounds to the cubic foot, but the piece weighed was rather more dry than the average of the piles,—they may be assumed to have averaged at least 40 pounds per cubic foot."

An example follows giving an application of the formula, and making $L = 118{,}175$ pounds, claimed to be an average value for piles driven.

"Each pile supports 28,575 pounds. They have been loaded with 23,800 pounds since the fall of 1846 (three years), and the total now is 28,575 pounds."

"Bastion A, the bastion nearest the channel, was finished in the fall of 1846, with the exception of the parapet wall surmounting the scarp. In that bastion the piles were longer and heavier and they also went further under the last blows. The formula applied to those in the neighborhood of the salient would give about 85,000 pounds as the load they could sustain. They have sustained for three years 23,700 pounds each; the parapet wall will add about 4000 pounds to each pile."

"Thus, Fort Montgomery gives three years' experience in favor of a coefficient of stability of 3 6-10 when applied to the calculation, under the supposition of a constant force."

In discussing the theory further, he closes as follows:

"There might be circumstances perhaps to make the intensity of the retarding force greater at some intermediate moment than at the commencement or close of the motion, as, for instance, *a very thin, hard stratum* just below the point of the pile; before the pile should reach it the penetration would be easy; it would be difficult while passing through it, and again become easy. But there were no such circumstances in the cases in question. The borings in Bastion A, down to the depth of 35 feet, gave a mixture of a very fine clay and sand, so fine that, when dried and rubbed between the fingers, it made an almost impalpable powder.

"Many cases occurred in which after a pile had been driven some days another blow was struck, and the result was *invariably* a less motion than was to have been expected if this blow had immediately succeeded the others. One of these cases occurred in which a pile that on the 18th of September was driven from $4\frac{1}{4}$ to $5\frac{3}{4}$ inches on the last four blows, on being struck again on the 20th of September was driven but two inches."

"In stating the average weight with which the piles are loaded, no deduction has been made for the influence of the water (in the spring months) in reducing the weight of the masonry. In certain seasons, and for a short time, this might reduce the loads from four to five per cent.

Table showing the circumstances under which some of the piles were driven (77 given in the memoir):

No. of Pile.	Kind of Wood.	Diameter of Pile in inches.		Length before and after cut off.		Fall of Hammer at the last blow.	Several penetrations of Pile with a few of the last blows in corresponding order. Inches.
		Butt.	Point.	Before.	After.		
1	Spruce.	12½	9¾	32 11	32 0	34 10	5¼-4¼-3⅞-3⅝-3½.
2	"	17½	13	33	31 2	33 11	4¼-3⅝-3⅛-2¾-2⅜.
3	"	14	11½	32	31 4	35 1	10-6⅞-5½-4⅝-4⅛-3⅝.
4	"	14	9¾	33	31 8	34 5	5-4½-4-3½.
5	"	13¾	10¼	32	32 0	36 0	5¼-4¾-4⅜-4⅛-3¾.
6	"	14¼	10¼	32	32 0	35 10	5-4⅝-4⅝-4⅛-3⅜.
7	"	14¾	10	32	31 10	35 7	4¾-4¾-4½-4¼.
8	"	14¾	10	33	32 1	34 10	5¼-4½-4⅛-4-3⅝.
9	"	14¼	10½	32	31 5	35 3	5⅜-5-5-4½.
10	"	14	11	33	32 9	35 8	4-3½-3¼-2⅞-2½.
11	"	12	9½	33	33 0	35 9	5-4¼-3¾-3½-3⅜-3⅛-3-3.
12	Hemlock	14	11	29	29 2	35 1	11-10¼-9½-9¼-7¾-6½.
13	Spruce.	13¾	9	31	30 2	35 1	10-8¾-6⅜-5-4½-3⅞.
14	"	14½	12	31	30 2	34 11	6-4¾-3¾-3½-3.
15	"	12¾	9¼	31 4	31 0	35 8	9¼-6½-5-4¼-3¾-3¾.
16	"	13¼	9¾	30 9	30 6	35 9	6-5-4½-4-4¾.
17	Tamarack	15	11½	29 11	29 2	35 1	8-7-6-4¾-4¼.
18	Spruce.	15½	11¾	32 1	28 7	32 6	5-4-3¾-3½-3¼-3-2¾.
19	"	16	14¾	31 9	28 1	32 1	5-3¾-3¼-3-3-3-3¼.
20	"	12¾	9¼	31 6	31 1	35 3	17-11-7¾-6¼-5-5¼.
21	"	13	9¾	31 0	30 6	35 3	29-27-16-9¾-6½-5.
22	"	14½	10¾	32 0	29 2	33 3	9½-7-5¼-3¾-3¼-2¾.
23	Hemlock	15¼	10½	31 10	29 10	34 1	6⅛-5¼-4¼-3⅞-3⅜.
24	Spruce.	16	11	31 4	29 11	34 5	5⅜-4¼-3¾-3⅜-3⅛.
25	"	13	10	32 5	30 5	33 10	7¾-6¼-5⅛-4½-3¾.
26	"	14¼	10¼	32 0	29 9	33 8	5-4½-4-3¾.
27	"	14	10	33 0	31 4	34 5	5½-4½.-4¼-4-3¾.
28	"	13½	9½	33 0	31 4	34 4	5¼-4¾-4½-4-3¾.
29	"	15	9¼	33 0	32 6	35 5	3⅜-3¼-3-3-3-3.

From these extracts we see that Colonel Mason did not obtain his formula from ultimate loading. He obtained it from theory and then "tried it on," figuring out a factor of safety of 3.6.

It is stated that there has been some settlement since 1850 (Van Nostrand, 1882). Best recent information is that settlement stopped 1886.

Chief Engineer Jos. G. Totten, U. S. Army, seems to have inspired his men to do original work; and we come to another example of this in the work of Brevet Major John Sanders.

The following is his well-known paper:

MAJ. JOHN SANDERS—FORT DELAWARE.

For the *Journal of the Franklin Institute.* "Rule for Calculating the Weight that can be safely trusted upon a Pile which is driven for the Foundation of a Heavy Structure," by John Sanders, Brevet Major U. S. Engineers.

"A simple empirical rule, derived from an extensive series of experiments in pile-driving, made in establishing the foundation for Fort Delaware, will doubtless prove acceptable to such constructors and builders as may have to resort to the use of piles, without having an opportunity of making similar researches.

"I believe that full confidence may be placed in the correctness of this rule, but I am not at present prepared to offer a statement of the facts and theory upon which it is founded.

"Suppose a pile to be driven, until it meets such an uniform resistance as is indicated by slight and nearly equal penetrations, for several successive blows of the ram; and that this is done with a heavy ram (its weight at least exceeding that of the pile) made to fall from such a height that the force of its blow will not be spent in merely overcoming the inertion of the pile, but at the same time not from so great a height as to generate a force which would expend itself in crushing the fibers of the head of the pile.

"In such a case it will be found that the pile will safely bear, without danger of further subsidence, '*as many times the weight of the ram as the distance which the pile is sunk, the last blow is contained in the distance which the ram falls in making that blow, divided by eight.*' For example, let us take a practical case in which the ram weighs one ton and falls six feet, and in which the pile is sunk half an inch in the last blow; then, as half an inch is contained 144 times in 72 inches, the height the ram falls, if we divide 144 by 8, the quotient obtained, 18, gives the number of tons which may be built with perfect safety in the form of a wall upon such a pile.

"Fort Delaware, September 27, 1851."

GENERAL RICHARD DELAFIELD—FORT DELAWARE.

As to the experiments themselves, I will refer to "Foundations in Compressible Soils," 1868, by Richard Delafield, Brevet Major-General. General Delafield is the "Captain Delafield" of the memoir, and was therefore connected with the work at Fort Delaware in 1833 and later. He says:

"Major Sanders's experiments at Fort Delaware were made with a view of deducing a rule for foundation on compressible soils, without any firm substratum lying within reach of piles, for calculating what weight each pile would bear with safety, by comparing the distance it was sunk at the last blow with the force of the blow, it being understood that the pile has been driven to such an extent that for a number of blows the penetration has been uniform for equal blows.

"To ascertain such a rule two sets of piles, of four each, were driven, and a platform built on their heads; they were then loaded with blocks of stone piled regularly on the platform; and at regular intervals of time the amount of subsidence caused by the weight, which was periodically augmented, was noticed.

"These piles were 12x12 inches x30 feet yellow pine. They were not driven through the alluvial; their points were about 20 feet from the sandy sub-soil, so that their stability was due to the accumulated and constantly increasing resistance of the same medium. In one experiment the four piles were driven to a depth of about 24 feet each, with a pile-driver that struck thirty-four blows in a minute, with a ram of 2000 pounds and a uniform fall of 6 feet. An artesian well sunk on this island in 1834 found mud continuously to a depth of 46 feet below low water mark; then 20 feet of sand; then 30 feet of coarse sand containing shells. It then entered and penetrated for 47 feet a bed of marl which contained boulders.

"At the penetration of 24 feet each of the blows of the ram drove them about an inch, or exactly 1-74 of the fall of the ram.

			Settlements.	
Loads on the 4 piles	Time. Months.	Total Time. Months.	Distance in 1-32 inches.	Total Dist. in 1-32 inches.
60,700	6	6	6	6
75,700	..	..	0	6
94,000	1	7	2	8
94,000	3	10	0	8
107,500	1	11	1	9
121,800	8	19	7	16
121,800	33	52	0	16
134,000 147,000 160,000 174,000	7	59	0	16
189,500	17	76	10	26
189,000	48	124	6	32

"The conclusions that may be derived from it are obvious; that the subsidence had ceased may be safely assumed. It follows that a building on piles, driven in soils exactly of the nature of that in which these experimental piles were placed, will be safe if we do not load them with a greater weight than $\frac{Wh}{3S}$ The coefficient was, however, fixed by Major Sanders for safety at $\frac{1}{8}$.

"Conversely, having given the weight of the superstructure, we can by the same rule ascertain the minimum number of piles that will sustain it, if driven to a fixed depth, or the depth to

which an approximately fixed number of piles must be driven to effect the same purpose.

"There were two experiments of the kind we have described made at Fort Delaware. The second one continued three and a half years, had similar results and was equally regarded in the determination of the coefficient used in the rule.

"From other experiments made during the same period Major Sanders ascertained the relation between the living force of the ram and the distance the pile is sunk for *different falls*, by a series of experiments on 64 piles which received 1900 blows from a ram of 800 pounds. It was found that when the fall was less than 3 feet the useful effect was extremely small; that it gained in a rapidly increasing ratio as the fall was augmented, a foot at a time, to 5 feet; and that at this point the ratio of useful effect to the force expended is at its maximum, and that the piles are driven to distances proportional to the blow; or, in other words, that there is nothing gained by increasing the fall beyond 5 feet. For example, two blows of 5 feet will sink a pile as much as one blow of 10 feet; three blows as much as one of 15 feet; four blows of 5 feet as much as one of 20 feet.

"It was also found that if the 5-feet blows followed each other in rapid succession, the useful effect was rather greater than if the interval employed in common hand-power machines for hoisting the ram was allowed to elapse.

"From 1833 to 1838, 11,000 piles of 45 feet in length, 12 inches square at head and not less than 10 inches diameter at the small end, were driven for the foundations of Fort Delaware, under the superintendence of Captain Delafield of the corps of engineers, with a hammer of 1800 pounds, by blows in quick succession with steam power, the maximum fall of the hammer being 45 feet. Since 1850, 4500 additional piles were driven, under Major Sanders' superintendence; from which experience he has drawn the preceding deductions. Sixty-six hundred of these piles are under the scarps and casements of the present work.

"In 1848 the excavations for the foundations of the work existing at this time (1868) were commenced, and completed in 1849, and the piling by Major Sanders heretofore referred to was finished in 1851. By 1853, 2000 tons of masonry had been laid on these piled foundations, and in 1859 the walls, arches and other masonry were finished.

"Three bench-marks were established in 1854, reference to which was made in 1859, when it was found that the masonry had not settled in any part. From 1859 to October, 1866, the settle-

ment in reference to the above bench-marks was 4 inches at the maximum point and 2.65 inches at the minimum, and a mean settlement for all the observed points of 3.19 inches. No crack was perceptible in any part of the work in 1866 or in 1868."

Recent observations (1897) show that the fort stands with a single small unimportant crack in one casemate arch.

It is well to note here that Sanders considers the ultimate load as $\frac{Wh}{3S}$. So when he recommends $\frac{Wh}{8S}$ he assumes a factor of $2\frac{2}{3}$ only.

Also that his experiments show that the sustaining power varies directly as "h" when the drop is 5 feet or over.

PENSACOLA NAVY YARD, FLORIDA.

Various authorities give results of tests at Pensacola Navy Yard Dock, built in 1851-52.

The soil is clean white quartz sand to a depth of about 40 feet, resting upon a bed of soft clay. The sand is so open that a cubic foot saturated contained 6 quarts of water.

A space 140 x 180 feet was enclosed by driving yellow pine piles 12 inches square to a depth of 20 feet in contact with each other, forming a cofferdam. Within this space the sand was excavated to a depth of 14 feet below tide. Piles 4 feet centers driven until a 2200-pound ram fall 30 feet could not move them more than $\frac{1}{2}$ inch.

A series of experiments were made under the direction of a special board of officers. The upward tests are what interest us. The trial pile was about 29 feet long, 16 feet in sand; diameter, $13\frac{1}{2}$ inches; weight, 1632. Tested two months after it was driven.

TABLE OF TESTS.

Pounds.		
78,000	no movement.	Rose $2\frac{1}{2}$ ins. in 30 min.
80,000	resisted $\frac{1}{2}$ minute and then rose very slowly.	
82,000	$1\frac{2}{3}$ min.	
83,000	$\frac{1}{2}$ min.	
60,000	18 hours. No movement.	
64,000 74,000	Rose 3 ins. in one hour; 6 ins. in all.	
50,000	for 2 days. No movement.	

A single pile used as a fulcrum sustained 39 tons. Tests showed that piles which one day penetrated 6-10 inch penetrated $\frac{1}{8}$, $\frac{1}{2}$, 6-10 inch by three successive blows the next day, the blows being given in one minute. "If the pile is allowed to remain undisturbed a short time, the power to move it afterwards *must be greatly increased*."

This is worth noting, and also the *method of continuous testing.*

A. C. HURTZIG—HULL DOCKS.

Further experiments on pulling piles are given by A. C. Hurtzig, Associate Member Institution of Civil Engineers, in 1881, Albert Dock, Hull.

The material was compact bluish clay. Above it was from 3 to 5 feet of peat, above which again were silt and sand.

The piles were 5 feet apart and formed a dam. It was made in 1874 and piles were drawn in January and February, 1880. That is, they were five years in the ground. The piles may be considered as having been chiefly in the stiff blue clay. Before the piles were drawn the clay puddle between the two rows was removed to as low a point as possible, which was about 13 feet below the level of the quay, or rather under high water mark of ordinary neap tides. The clay puddle that could not be removed would increase to a small extent the frictional resistance to drawing. A "cat-head" was used to draw the piles, with frame, chain, and winch. To the lower pulley-block a heavy sling-chain was attached, and this was slung around the pile to be drawn and secured by wedges. The power exerted by one, two or more men was ascertained by allowing them to lift certain known dead weights with the winch and tackle. Six men could haul up 41.0 tons. Five men could haul up 35.5 tons, etc.

'It would have been easy with a dynamometer to have had the exact pull taken, but no such instrument was available.

There were 420 piles drawn, upon which 300 observations were taken. The length varied between 29 feet and 49 feet; average length, 40 feet; average scantling, $12\frac{1}{2}$ inches square = 156 square inches, the sizes varying between 12x10 and 15x14. The depths to which the piles were driven in the ground ranged between 6 feet and 30 feet; average, $18\frac{1}{4}$ feet; average superficial area of pile below the ground line, 76 feet.

The piles were not tongued and grooved, but driven close together, so that only two sides could be taken as frictional area, or 38 square feet. For 300 piles the gross resistance per pile was 33.87 tons. From this must be deducted two items, the weight of the pile and the power required to overcome suction.

The net frictional resistance, 31.82 tons, and this was on an area of 38 superficial feet, gives 1875 pounds as the friction per square foot in contact with the soil. The piles were of ordinary rough Memel balk timber. With sawn timber there would probably be a slight reduction in the friction.

The piles in the dam were driven by 1 ton ram falling 5 to 6 feet. Penetration, ½ inch to ¾ inch per blow.

H. LENTZ—CUXHAVEN HARBOR.

We also have a description of the method of pulling piles by simple tidal action, Cuxhaven Harbor, by H. Lentz.*

The piles were in fine drift sand, which held them remarkably fast. A trial pile 3.23 feet in circumference, driven to a depth of 15.7 feet, was extracted by a pull of 7 tons 16 cwt. after 23 days in the ground. Numerous piles, on the average 17 inches in diameter, required pulls of from 23.5 tons to 28 tons 15 cwt. after having been embedded from 10 to 20 years at a similar depth.

Having used a rowing barge with windlass, and found it somewhat awkward, the author constructed a large timber box 22x19x6½ with slit or bay 34 inches wide, reaching from the middle of one of the longer sides to beyond the center of the box. When totally immersed, the pull was 59 tons. By means of an oak beam laid over the center of gravity of the box and attached by chains to the piles, these latter could be floated out as before. In some cases 50 and 55 tons had to be exerted before the pile could be moved, but in no instance was the full power of the box, 59 tons, brought into requisition.

W. J. M'ALPINE—BROOKLYN DOCK.

We come next to the valuable paper of W. J. McAlpine, Past President American Society Civil Engineers, on "Pile-Work at the Government Graving Dock, Brooklyn," which was presented to the Institution of Civil Engineers, 1868. Extracts as follows:

"The absence of any reliable data in the text-books upon the weight which may be safely imposed upon piles has led the author to present the subject, under the hope that it may call out the recorded experiences of other engineers, for the purpose of comparison with, and perhaps a correction and extension of the formula prepared from an extensive set of experiments made for the purpose in 1847.

"Piles are used under the three following conditions: *First*, to compact a soil which is not quite firm enough alone to support the superstructure; *second*, as columns of support, when the material immediately below the structure is very loose or fluid, and is underlaid by a firm material to or into which the piles are driven; and *third*, when the support is mainly derived from the adhesion of the material into which they are driven, and slightly from their sec-

*Deutsche Bauzeitung, 1879, quoted by Institution of Civil Engineers, 1880.

tional area. The first two of these conditions will not be discussed, but the present paper will be confined to the practical hints growing out of the author's experience in driving a large number of piles of different kinds of timber and of different dimensions, and with rams of different weights and falls and the use of various kinds of power.

"The Government Graving Dock at Brooklyn, N. Y., is a structure of granite masonry weighing 50,000 tons, the walls of which commence 36 feet below the sea level, and the excavation was carried 4 feet deeper.

"A considerable portion of the foundation had to sustain a weight of 3 or 4 tons per square foot. A line-of-battle ship weighing 5000 tons would require to be mainly supported on its narrow keel within a length of 200 feet, which gives an estimated weight upon the keel of about 20 tons per lineal foot. The grillage and foundation distribute this weight, but the center piles are probably subjected to a weight of from 10 to 15 tons each.

"The material removed from the excavations was a fine silicious sand, mixed with minute particles of mica and a little vegetable loam and fully charged with water, rendering the mass somewhat fluid, resembling quicksand, which it did become to a depth of several feet wherever it was much trodden by the workmen.

"Borings were made and trial piles were driven to a depth of upwards of 50 feet below the excavation. These indicated the same character of material to that depth, and it was believed to extend 50 feet or more below the borings. The structure rested on about 7000 piles, which were driven in rows $2\frac{1}{2}$ feet apart, and at a transverse distance of 3 feet all from center to center. Intermediate piles of very tough second-growth oak were frequently driven. The main piles were chiefly round spruce spars, very straight, from 25 to 45 feet long, averaging a driven length of 32 feet. They were not less than 7 inches in diameter at the smaller end, and on an average of 14 inches in diameter at the larger end. The heads of the piles were always protected in driving by bands of iron 3 inches by 1 inch, and occasionally iron shoes were used, but they did not increase the penetration, as the resistance was chiefly from the *lateral friction*, and the tenacity of the pointed wood was sufficient to displace the material at the bottom.

"During the progress of this portion of the work a careful record was kept, which showed the distance moved by every blow on every pile used in the structure, and the weight and fall of the hammer at each blow. From this record it was ascertained that

the number of blows required to drive 6539 piles in the foundation an average depth of 32 feet was $2\frac{1}{3}$ to each foot of pile, and the distance moved uniformly diminished from the first to the last blow, ranging from 8 inches at the beginning to no movement at the end, and the *average distance driven by the last five blows was 1 inch.* The effect of driving the intermediate piles by compressing the material was to bring them all to the point of ultimate resistance. The piles were secured at the top by a mass of concrete masonry 3 feet around the heads, and by a grillage of timber, plank and concrete $2\frac{1}{2}$ feet thick at the top. The piling machines were strongly and accurately made, with the ways bound with smooth plates of iron. The rams were of cast iron, swelled out at the bottom to concentrate the weight at that point. They weighed generally about 2200 pounds, but some were used of 1500 pounds. The leaders generally gave a fall of 30 feet to the ram; but some machines were tried with leaders of various lengths up to 57 feet.

"A considerable number of piles were driven by a Nasmyth steam piling machine, with a ram of 3 tons and a stroke or fall of 3 feet, and making 60 to 80 strokes per minute. The other machines were generally operated by steam power, giving an average of a blow per minute; but occasionally the hammers were hoisted by manual or horse-power. It was observed that the heaviest ram, when striking blows of the same effect as lighter ones, did the least injury, either to the head of the pile or to the protecting iron ring, and this injury was still less with the Nasmyth hammer. It was also found that *no advantage was gained by increasing the fall of the ram beyond 40 feet*, as the friction on the ways then prevented any increased velocity to the ram when falling from a greater height. This experiment was repeated many times in the machines with the longest leaders by tripping the hammer at various heights, from 35 feet upwards, until the maximum penetration of the same pile was ascertained. A few of the piles, under peculiar circumstances, had to be driven with a follower, which was made of very tough oak, and well banded at both ends. The effect of the blows of the ram was about *one-third* as much as when directly striking the head of the pile. The Nasmyth hammer was capable of driving the piles to a much greater depth than any of the other machines, and although the force of its blows is much less than those of the ordinary rams when falling nearly 30 feet, it produces a much greater effect. With the former, piles were driven 35 feet in 7 minutes, while with the other machines similar piles required one hour or more to drive them the same distance. Two trial piles were driven with each of these machines, with the following results:

TABLE 1.

Pile driven by the Nasmyth Machine.

The first	4 blows drove it	4 ins. each blow.
Next	8 " " "	3½
	22 " " "	3
	25 " " "	2
	40 " " "	1¾
	56 " " "	1½
	32 " " "	1¼
	64 " " "	1⅛
	73 " " "	1
Last	49 " " "	½
	373	

"This pile was nearly the same size as the other trial pile, and was driven 43 feet in 7 minutes with 373 blows, and was not iron-shod.

TABLE 2.

Pile driven by a ram weighing one ton falling from ½ ft. to 35 ft.

The first	100 blows drove it	a few feet.
	260 " " "	30 ins. in all.
	265 " " "	from ½ in. to 1½ in. at each blow.
	110 " " "	1¼ in. at each blow.
	735	

"This pile was driven 45 feet with 735 blows. It was 20 inches in diameter at one end and 14 inches at the other, and was shod with iron and occupied 166 minutes in the driving,—viz, 264 blows in 46 minutes, 265 blows in an hour, and 110 blows in an hour.

"The ordinary piles were smaller and shorter than these trial piles, and the ram in the common machines began with a greater fall than above stated, on the trial pile, and there was not so marked a difference between the two machines in the first part of the operation as was shown afterwards when the pile had penetrated deeper. At first the force of the blows in each of the machines was absorbed by the vibrations of that part of the comparatively slender, elastic column which was above ground; but when it had been driven a considerable distance into the earth these vibrations for the instant removed the partially fluid material from contact with the pile for nearly the whole of its penetration.

"In the case of the Nasmyth machine the blows succeeded each other at intervals of a second of time, and before the material which had been displaced by the vibrations of the preceding blow could

subside again into close contact with the sides of the pile, and therefore nearly the whole force of its blows was employed in the displacement beneath the pile.

"In the other machines the blows were given at intervals of a minute, by which time the vibrations caused by the preceding blow had ceased, and the semifluid material had partially subsided around the pile, so that a considerable portion of the force of the blows was consumed in overcoming the friction along the sides, and in the removal by new vibrations, leaving only a comparatively small part of the force to displace the earth at the bottom of the pile.

"As before stated, the pile derives its support mainly from the frictional surface in contact with the earth, which is measured by the force of the blow due to the weight and velocity of the ram. The ram, however, does not fall in free space, but meets with great resistance along the ways, depending upon their smoothness and the strictly vertical position of the machine at all times.

"In wet foundations the material obtains a degree of fluidity when disturbed by the operation of driving which lessens the resistance to the penetration of the pile; but the superior gravity of the earth to that of the water causes it subsequently to settle in close contact with the sides of the pile, and if not afterwards disturbed gives a greater coefficient of support than if the same pile had been driven through the same kind of material in a dry state. In using comparatively slender piles the vibrations caused by the blows enlarges the passage and loosens the material, and although they absorb much of the power, they doubtless increase the penetration at each blow.

"It would be hazardous, however, to trust to the effect of this subsidence in a superstructure which is liable to vibration, and to convey these vibrations to the piles; but when there is a large mass of matter intervening, like that of the masonry of the piers of a bridge, there is no danger from this cause.

"Experiments were made at different times during the progress of the construction of the dry dock to ascertain the weight which the piles driven in the manner described would sustain. For this purpose one end of a lever of oak timber 60 feet long was firmly secured to a cluster of piles with a short arm resting on the trial pile. The bearings were angular steel bars resting on planed plates of iron. The outer end of the lever was slowly weighted with successive weights, which towards the latter part of the trial were allowed to remain several hours, and in a few cases a whole night. A number of the foundation and cofferdam piles were

withdrawn by a similar process, and the power required was also ascertained. Many of these trials were made on piles of nearly the same size and driven in exactly the same manner, and the results were in all cases nearly alike, giving 125 tons as the weight required to move a pile driven 33 feet into the earth to the point of ultimate resistance [$s=0$] with a ram weighing one ton (2240) and falling 30 feet at last blow. These trial piles averaged 12 inches diameter in the middle.

"The complete record of the driving before referred to also enabled the selection of piles for some other experiments of different sizes and driven with rams of different weights and falls. As these trials had to be continued until the final weights applied produced a visible movement of the pile, and as some allowance must be made for the friction and imperfection of the lever attachments, and for the support of the sectional area of the pile, it was believed that the extreme supporting power of this pile due to its frictional surface was 100 tons, or 1 ton per superficial foot of the area of its circumference.

"From an analysis of these experiments the following general laws seem to have prevailed in these cases:

"*First.* That the effect of lengthening the fall of the ram was to increase the sustaining power of the pile (driven as before mentioned) in the ratio of the square root of the fall.

"*Second.* That by adding to the weight of the ram the sustaining power of the pile was increased by 0.7 to 0.9 of the amount due to the ratio of the augmented weight of the ram.

"*Third.* That a pile driven by a ram weighing 1 ton and falling 30 feet will sustain an extreme load of 100 tons.

"The author is of opinion that under the most favorable circumstances the pile should not be loaded with more than *one-third* of the result given by his formula, and where there is any danger of a future disturbance of the material around the pile, or when there is any vibration in the structure which may be communicated to the piles, the load imposed should not exceed *one-tenth.*

"In the preceding discussion the bearing support due to the sectional area of the pile has not been considered, as it forms so small a portion of the support. Numerous experiments have been made which give results of from 5 to 10 tons per square foot."

The formula is as follows, in terms of "h" and "w" only:

$$L\ (\text{tons}) = F\ 80\ [0.228\sqrt{h} + w\ (\text{tons}) - 1]$$

The discussion which followed was an interesting one. Sanders's formula was generally spoken well of, while the above was

spoken of as applicable only to the conditions which prevailed at the Brooklyn Dock.

I will quote only T. D. Ridley, who said:

"Eleven years ago (1857) I drove a large number of piles for the foundations of the viaduct which carried the Border Counties' Railway across the river Tyne at Hexham. The bed of the river consisted of compact boulder gravel and sand, which latter material, when it contained water and had a superincumbent load, was perhaps the most difficult substance through which it was practicable to drive piles. After the first few blows none of the piles descended more than $\frac{3}{8}$ inch for each stroke and at depths ranging from 16 to 33 feet they responded only $\frac{1}{8}$ inch to the final falls of the hammer. Rams weighing 2000 to 2400 pounds were found to be of little use in this case, and the piles usually failed under the high fall of 16 to 20 feet which was required to force them downwards. Seeing the injurious effect, a ram of 5000 pounds was used, and by giving a fall of from 8 to 12 feet, and never exceeeding the latter limit, the piles were successfully driven. The conclusions there formed as to the superiority of a heavy hammer with a low fall over a light ram with a long stroke in difficult ground, had been amply confirmed by subsequent experience."

The practical nature of McAlpine's first two conclusions is seen if we suppose the case of a set of specifications calling for a certain weight of hammer, while the contractor is using another weight. Opinions differ on this point. McAlpine says the sustaining power varies as the square root of "h" (that is, according to the law of falling bodies); Sanders as "h" directly, while Trautwine, also from experiment (see "Pocket Book"), says the cube root of "h," etc.

Only McAlpine has made experiments of the kind indicated in his conclusion No. 2.

It might be well to say here that specifications should also cover any correction for batter of piles, or for the effect of rest already mentioned. In this last case the contractor would claim the benefit, if any, resulting therefrom.

In several of the preceding papers there has been mentioned the fact, well known among pile-driver men and the profession, of the increased resistance, under some circumstances, of the pile after a period of rest. Exact data, with time limit, if any, are wanting. Also data on the effect of a persistent quiescent load. It is customary to tap a pile before pulling it with the hammer line or tackle.

CHARLES COLSON—PORTSMOUTH DOCK.

An interesting set of tests bearing on these points is found in Mr. Charles Colson's paper on Portsmouth Dock Extension (Inst. Civ. Engrs., 1881).

After tabulating the results of the driving of 12,088 piles, wherein is given nearly everything except the ultimate sustaining power, he applies formulæ, getting safe loads of fifty, sixty and seventy tons per pile. The strata are those immediately below the London clay, consisting of compact sandy beds, containing masses of hard concretionary stone or shell rock; some not containing the shell rock, and some driven to a still lower stratum of hard clay.

The last sets were about $\frac{1}{4}$ inch from the fall of a 1600 pound ram; height, 20 feet.

"During the progress of the work it was observed that on the resumption of driving, after an interval of some hours, the set of the pile was invariably much less than that observed on the cessation of driving, the fall of the ram being the same. This result is to be accounted for, in a great measure, by the fact that during the process of driving the ground is to a great extent disturbed; the vibration also of the pile causes the hole, from the surface downward, to be slightly enlarged, thus relieving the pile from the full frictional resistance.

"In order to obtain information as to the extent of such increased resistance accruing from quiescence a number of special observations were made upon piles, the driving of which was completed, or nearly completed, immediately before leaving work for the night, as many as possible of the piles which gave an excessive first set being included. On the following morning one test blow of the ram, with a full fall, was given, and the resulting set compared with that recorded on the previous evening. It is shown by these observations that thirty-nine beech piles, averaging 13.076 feet in length, 123.863 square inches in sectional area, and showing 0.0540 feet set, gave, when tested the following morning, an average set of 0.0234 feet, showing an increased resistance in the ratio of 2.30 to 1.

"Seventy-four fir piles, averaging 19.74 feet long, 162.70 square inches sectional area, and showing 0.0366 feet set, gave, when tested the following morning, an average set of 0.0130 feet, showing an increased resistance in the ratio of 2.81 to 1."

Applying these new values in the formula he gets what he calls "augmented stability," running from 118.77 tons to 232.21 tons.

"These ratios have been calculated on the assumption that the whole pressure is supported by the piles; an assumption which is untenable, inasmuch as the whole space between the piles and up to the under side of the longitudinal sleepers being filled in solidly with Portland cement concrete, the pressure is of necessity distributed over the whole area of the foundation; in fact, particular care was taken to insure this condition.

"During the progress of the pile foundations, observations were made with a view of obtaining data on which to found some idea as to the extent to which the ground was compressed by the piles. The effect of driving was to raise a cone of earth around the pile, the base extending to a varying distance; this being repeated by the driving of each pile, produced a raised, undulating surface over the whole area.

"The ground consisted of the compact, sandy beds immediately below the London clay; the mean rise of the surface, due to the driving, was found to be 0.75 feet. Therefore, over an area of 52 feet by 24 feet, containing sixty-six piles, the heads of which averaged 1.33 square feet in area, the quantity of ground lifted would be equal to 870.17 cubic feet. Deduct one-quarter due to disintegration by driving, leaves 652.63. The quantity of timber driven as piles within the above area is 66x12x0.854, or 676.36 cubic feet. .

"Therefore, the displacement of ground due to the pile-driving will be equal to 96 per cent. of the whole quantity of timber driven."

Other ground "of a somewhat more argillaceous character" gave displacement 64 per cent. of the total quantity of timber driven.

Other strata still "of a compact blue clay," the upper surface being "more plastic and compressible," gave 47 per cent. of the total quantity of timber driven.

Results like these last give a definite idea as to whether the piles act as simple columns to transfer the load to strata underneath, or whether they act as compressors of the interfluent soil.

MAJ. E. T. D. MYERS—AQUIA CREEK, VA.

Further experiments on the value of quiescence are those at Aquia Creek, Va, Major E. T. D. Myers, 1885.

Bents $12\frac{1}{2}$ feet centers, six piles each, 15 to 18 inches butt, length 50 feet. Grade line 15 feet above low water; in use fourteen years. Piles driven in a liquid mud. Two bents, of six piles each, were driven, upon which a platform was placed, and upon this a

weight of 75,000 pounds, uniformly distributed. The experiment was made nineteen hours after driving.

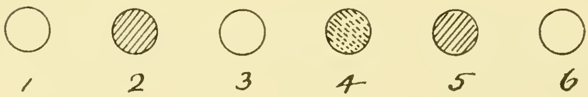
No settlement taking place, piles Nos. 2 and 5 in each bent were cut out, leaving four piles in each bent. Then No. 3 of the seventeenth and No. 4 of the eighteenth were cut out, leaving only three piles in each bent. About 5000 pounds was then added to the load, when No. 6 of the eighteenth bent yielded, followed by No. 3 of the same bent, and sank until Nos. 4 and 5 were again brought to bear.

It required, therefore, about 13,000 pounds each to start the piles. The record of the driving was as follows:

BENT 17.

Fall from 3 to 10 ft. 2000 lb. hammer.

Pile No. 1.	11 blows, last blow	7 ft.	11 in.
" " 2.	13 " " "	9 "	9 "
" " 3.	8 " " "	9 "	18 "
" " 4.	8 " " "	8 "	17 "
" " 5.	9 " " "	5 "	6 "
" " 6.	7 " " "	7 "	10½ "



BENT 18.

Pile No. 1.	12 blows, last blow	5 ft.	10½ in.
" " 2.	8 " " "	4 "	8 "
" " 3.	8 " " "	4 "	8½ "
" " 4	9 " " "	3 "	4 "
" " 5.	14 " " "	10 "	9 "
" " 6.	5 " " "	9.8 ft.	22 "

A pile 40 feet long, after sinking 30 feet with its own weight and that of the hammer weighing 2000 pounds, was struck with a blow of 2-feet fall, and then settled 6½ inches in one minute, by the weight of the hammer. Four weeks after this a blow with a fall of 5 feet did not move it. A blow of 14-feet fall drove it 4½ inches.

"Also at the Gunpowder River piles 40 to 50 feet long were driven until they did not sink more than 18 inches under a hammer weighing 1800 pounds falling 20 feet. Four piles to the bent. In neither case was a hard stratum passed through or reached."

W. M. PATTON, IN "FOUNDATIONS."

"This," says Mr. W. M. Patton in his "Foundations," "is but the common experience in the Southern swamps. In all cases above alluded to, these trestles have carried, without settling, the heavy trains of the present day."

Mr. Patton continues: "Some eight miles of trestle constructed under the writer's direct supervision in the Southern swamps, the bents containing four piles, spans 12½ feet, depth of pile in the soil varying from 30 to 35 feet, the penetration varying from 6 inches to 2 feet at the last blow of a 2000-pound hammer falling only a few feet, has carried *for twenty years the heaviest trains without any settling.* In the abutments of some of the bridges in these swamps the piles have carried with perfect safety 17,000 pounds to the pile. How much more they are capable of carrying is not known.

"In one of these abutments, piles only 30 feet in the soil could not be moved, by continued hammering, with high falls, a few days after driving. The experiment was made as the writer was not satisfied with the record of the original driving, and desired the piles to be driven to a greater depth. Finding it impracticable to move the piles, he determined to hammer one or two to destruction or move the piles; destruction was the result, and new piles were driven to take their place. We may therefore conclude that piles from 30 to 40 feet, in even the *softest alluvial soils* will carry, by frictional resistance alone, from 20,000 to 25,000 pounds, or 10 to 12½ tons.

"There are examples of piles driven in stiff clay to the depth of 20 feet that carry from 70 to 80 tons per pile; this is an unnecessarily heavy load, and when driven from 2½ to 3 feet centers they will rarely have as much as one-half the above loads to carry. There are many instances in which piles carry from 20 to 40 tons under the above conditions.

"In sand and gravel, piles will carry to the full extent of the crushing strength of the timber, provided the depth in the material is sufficiently great to prevent vibrations from reaching the point of the pile; other considerations will require this depth to be at least 10 feet or, at most, 20 feet.

"Any further hammering on piles in such materials is a waste of time and money, and injurious to the pile itself. To hit such a pile 100 to 150 blows to drive it an inch, as has been done, is simply folly."

In spite of this testimony in favor of increase of bearing power with time, there have been instances of failure, due to various causes, not expected at the time of driving. Perhaps the most noted one, excepting London Bridge, is that of the western arched approach to South Street Bridge, Philadelphia, where nine segmental arches, 43 feet 6 inches span, 14 feet rise, 55 feet width, were destroyed, owing to the failure of piles in one pier.

The following is the theory of the constructive engineer, D. McN. Stauffer,* to account for the stability of the structure for a period of six or seven years before failing:

"That at the south end of Pier No. 2 the piles were driven almost, if not quite, to the rock, there not being a sufficient thickness of hard material to prevent this being the case, and, as a consequence, that end stood firm; but at the north end of the pier, under the heavy driving, the piles penetrated almost *through* the hard stratum, say to within two or three feet of the upper limit of the 'mud pocket.'

"When this point was reached the direct and frictional resistance was sufficiently great to prevent further penetration. Just what this frictional resistance was, can, under the circumstances, only be estimated. Rankine's rule, as here applied, would give about 8 tons per pile. Be this what it may, from the nature of the material, it must have been considerable, and events prove that there was a sufficient amount of hard material between the mud and the toe of the pile to support the structure for a long time.

"But the tremor in the piles, produced by the heavy and constant travel over the approach, was in this case an element of destruction. This tremor had a tendency to loosen the pile from the impervious material into which it was driven and allow the surface water to slowly find its way down along the pile. In time this water would 'lubricate' the pile and destroy the frictional value of the mud, and constantly add *additional load* to that originally carried by the toe of the pile, which original load we will say, in this case, was 16 tons.

"Possibly before the whole of the 8 tons (previously carried by friction) was added to the 16 tons already on the toe, the safe bearing value of the hard crust was reached and the structure began to settle into softer material beneath it. Whether the piles punched through the crust or whether piles and crust sank together cannot be ascertained."

"No borings or test wells were taken previously."

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*American Society Civil Engineers, 1878.

MAJ. G. WEITZEL—PROCTORSVILLE TOWER, LA.

Another instance of failure is that of the pile and grillage foundation for Martello Tower, Proctorsville, La., 1856-57. Van Nostrand, 1882.

Major G. Weitzel says: "The site of the tower, as determined by actual borings, was found to have the following character,—viz:

"For a depth of 9 feet there was mud mixed with sand; then followed a layer of sand about 5 feet thick; then a layer of sand mixed with clay from 4 to 6 feet thick; and then followed fine clay. Sometimes clay was met in small quantities at the depth of 6 feet, as well as small layers of shells. By draining the site the surface was lowered about 6 inches.

The foundation piles were driven in a square of 20 piles on a side, 4 feet centers. Twenty-four piles were omitted to leave room for fresh water cisterns, and two extra ones were driven to strengthen supposed weak ones. Total number, 378. The piles were driven to distances varying from 30 to 35 feet below the surface, or from 10 to 15 feet into the clay stratum. The average number of blows to a pile was 55, and mainly hard driving. After all these piles were driven 10 additional hard ones were put in to strengthen supposed weak points. Each one required over 100 blows to drive it.

Before beginning the foundation I drove an experimental pile exactly in the center of the site. It was 30 feet long, $12\frac{1}{2}$x12 inches at top and $11\frac{1}{2}$x11 inches at butt. It was sharpened to a bottom surface about 4 inches square. Its head was capped with a round iron ring. Its weight was 1611 pounds, and the weight of the hammer was 910 pounds. Its own weight sank it 5 feet 4 inches, and it required 64 blows to drive it 29 feet 6 inches deeper.

"The fall of the hammer at the first blow was 6 feet, increasing each successive blow by the amount of penetration, excepting the last ten blows, when the fall was regulated to exactly 5 feet at each blow. The penetrations in inches were as follows for the last ten blows: $\frac{3}{8}$, $\frac{3}{8}$, $\frac{1}{4}$, $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{8}$, $\frac{1}{4}$, $\frac{3}{8}$, $\frac{3}{8}$, $\frac{3}{8}$.

"This pile, according to Colonel Mason's formula, should have borne 52,566 pounds. I loaded it with 59,618 pounds, and it did not settle. I afterwards increased the load to 62,500 pounds, when it settled slowly. The greatest weight to be carried by any one pile was *between 30,000 and 35,000 pounds.*

"The tops of the piles were sawed off on a level and the whole surface between them covered with a flooring of 3-inch planks tightly fitted in, the upper surface of this floor being flush with the

tops of the piles. They were then capped in one direction by stringers 18x18 inches x85 feet long. Each of these stringers was constructed by splicing, using the regular scarf joint. These were bound together by 12x12-inch stringers let into the 18x18-inch so that their top surfaces were flush. In the little squares thus formed, and next to the 18x18-inch timbers, were laid short pieces 12x12-inch timbers and the intervals filled in up to the level of the latter with concrete. The whole grillage was then levelled off with short pieces of 6x12-inch plank. This grillage was therefore 18 inches thick. Long sheet piling was driven for the scarp of the wet ditch, the upper ends resting on the inside of the stringers on the outer row of piles.

"In order to distribute the weight of the tower uniformly over this foundation, strongly reversed groined arches were turned, the space between their backs and the grillage being filled in with solid concrete masonry. When the brickwork of this tower, which was carried up evenly on all sides, was about half completed and the foundation had on it *less than half* the load it was designed to carry, the appropriation became exhausted and the work was stopped. This was in the spring of 1858.

"When I visited the work six months after I found *a marked settlement*. The four salients apparently remained intact, but on every side the settlement was about the same, and largest about the middle, so that the courses of brick, which were laid perfectly level, had the form of a regular curve."

G. T. Beauregard, Captain of Engineers, had ordered experiments to be made by Architect Roy, who had charge of the new Custom House at New Orleans, La., and these had been made in 1851-52. There were thirty-five tests made, with sizes of bearings on the soil varying from $\frac{1}{4}$x$\frac{1}{4}$ inch to 24x24 inches, and the conclusion was that, "contrary to the general opinion, a larger surface sinks more than in proportion to its area."

Major Weitzel further says: "The table of experiments sent by Mr. Roy, and the result of the experience gained at Proctorsville, La., show conclusively that although Mason's rule may hold good for an isolated pile, it cannot be depended upon for a system of piles such as are driven for foundations. In order, therefore, to determine the factor of safety for such foundations, the views and experiences of the officers of corps would be valuable," etc.

OVERLOADING STRATUM.

Considering this point of the entire bearing area, Mr. J. Foster Crowell says (Am. Soc. Civ. Eng., Aug., 1892): "It is quite pos-

sible to overload the stratum by driving piles too thickly; it is sometimes thought that if three piles, for instance, are good in a certain area, six will 'make assurance doubly sure.' This policy is not only costly and foolish, but in many cases it is dangerous. A certain public building in New Orleans, of which the author has heard, stands on an enormous number of square piles, driven so as to touch one another; in other words, there is a solid wall of wood, and instead of each pile having four surfaces in contact with the sustaining stratum, only the outer rows have contact, and they but on two surfaces; there are, therefore, from four to six times too many piles used, and the support is still much less than could have been obtained."

Other instances of failure not expected at the time of driving are given in American Society Civil Engineers Transactions, August, 1892, data by J. C. Trautwine, Jr.

PROF. FRANZ KREUTER.

Continuing the evidence, not strictly experimental, however, we have a paper quoted in Proceedings of Institution of Civil Engineers, written by Prof. Franz Kreuter, of Royal Technical High School, Munich, 1896. After explaining the merits of the formula,

$$L = F \frac{h_1 - h_2}{s_1 - s_2} W$$

he says: "Preparing to ascertain the supporting power of piles, by the method explained, the following precautions are of great importance:

"*First*. The piles should rest for some time, in order to allow the stresses produced in the ground by the penetration of the piles to be relieved. It has been stated from experience that piles frequently penetrate *with renewed ease* after some days' rest. An immediate test-driving might therefore lead to erroneous results, and to too high an estimate of the supporting power of the piles.

"*Second*. The head of the test piles should be sawn off to present a sound and solid surface to the blows of the hammer.

"*Third*. The number and force of the testing set of blows should be such as not to crush the head of the pile."

MR. CHARLES DAVIS JAMESON.

Again, Mr. Charles Davis Jameson (Member American Soc. Civ. Eng.) says (*R. R. and Eng. Journal*, 1889): "Another thing to be remembered in driving piles to a secure foundation is the difference between the ultimate load that is to rest on them and the quick blow of impact which is given them in driving.

"It is an established fact in mechanics, and also in practice, that a permanent load resting upon a pile will eventually have ten times as much effect upon it as that same load brought quickly upon it and as quickly removed. So that although the pile may penetrate a very little distance from each blow of the hammer, and the weight of the hammer, multiplied by the velocity which it has at the time of impact, may give a blow that in pounds is much greater than any weight that will come on it from its permanent load, still, after the permanent load has been resting some time upon the pile, we very often see examples where it begins to yield; the foundation sinks; and as in very few cases it sinks with regularity over its whole surface, the result is that, if the superincumbent load consists of masonry, one part sinks while the other does not, and there is a crack or fracture in the masonry."

Mr. Jameson apparently assumes that the pile receives its maximum skin resistance as it goes down, and does not increase it afterwards. He assumes that the same principle applies to pile-driving as to testing metals or timber in general; that is, that the ultimate strength may be made to depend considerably upon the time occupied in testing.

No experiments accompany his statements.

In several of the preceding papers much has been said in praise of the Nasymth type of hammer, and much more can be said on that point. At the present time it is rare to see one hereabouts. For sandy soils, there was a question at one time whether it was not more economical than any driver. The following report of Lieut. F. N. Abbot, U. S. Engineers, discussed the matter (Chicago, 1883):

LIEUT. F. N. ABBOTT—WATER JET, ETC.

"The water jet drivers on the long average do as much or more than the (Nasmyth) steam hammer; and this in the class of work now under execution here, where the machine shops of the company are available at any instant.

"The leads last between three and four times as long with the steam hammer as with the drop hammer. A hammer line lasts the steam hammer one month, while it needs replacing about once in five days with the other form. Say it will drive 500 piles on a jet, 3000 on the steam hammer driver.

"The steam hammer leaves the pile head as good as it was before driving, while the jet driver injures the head to a considerable extent. On this account, in contracts for wharf work, it is

not infrequently stipulated that all piles be driven by steam hammering.

"On a car, in land driving, the steam hammer is immeasurably superior, as there is much less jar and the water needed is not excessive.

"Sixty-five piles a day are expected of every driver in the Lake Shore protection; if less are driven the matter is looked into. Hard bottom is liable to reduce this number very largely."

As to the possible economy of using steam hammer drivers on the Mississippi River, he says: "The cost of the Illinois Central Railroad driver of this form was:

Steam hammer (of weight 7500 lbs.)	$1,593.50
License to build and use	500.00
Hull	2,000.00
Boiler and engine	2,333.59
Total	$6,427.09

"The weight of this size of hammer is too great for cottonwood piles; the second size, weighing one-half as much, would be what is required. Its cost, free of license, if obtained direct from the manufactory, is (price 1883) $875. The only possible saving would be in lessening the time now spent in actual driving, and this, with our present form, is but a small fraction of that needed per pile. The difference in the cost of the present hammer ($80) and the steam hammer ($875) is $795, and under the most favorable circumstances it would take a long time to pay for itself. The more simple the machinery used the greater is the chance of real efficiency when the work is carried on, as under this office, at a distance from machine shops.

"If any saving is to be made by extensive change of plant it must be found in some method of driving more than one pile from each position of the flat, thus eliminating partly the slow and vexatious changes of position in severe currents."

Major O. H. Ernst further says: "Lieutenant Abbot ascertained that the rapidity of penetration of piles sunk by the water jet and hammer combined is remarkably uniform when the average of a great number of piles is considered, and when the depth does not exceed 16 feet, the rate being about the same for the last two feet as for the first two."

It is not stated what is the cost of a pump to feed the water jet. This item would reduce the balance of $795 referred to.

The price of steam hammers to-day is not more than one-half

the figures given. However, the manufacturers do not claim a superiority in sandy soils. In general they claim a superiority for foundations of buildings, docking and certain other classes of work. There has been recent evidence in support of their claims.

D. M. CURRIE—PILES DRIVEN BUTTS DOWN.

The jet has another advantage. Piles may be easily driven butt down, as appears in the report of D. M. Currie, U. S. Engineers (St. Louis, 1881), as to work on the Mississippi River. He says:

"There were in this place strong scouring currents, with line of piles broken by ice at times. The piles were prepared for driving by sharpening the butt ends with glut points before they were placed in the water. They were driven 8 or 10 feet in the gravelly bottom, the hammer was lowered and used in connection with the jet, tapping the pile lightly with 2-foot fall, which, by keeping the pile continually in motion, prevented the sand from settling around it and stopping its progress. The piles were usually driven about 13 feet, and the actual time of driving was about 4 minutes.

"The saving in cost of driving the piles does not represent the whole advantage gained in using the jet. The piles being driven butts down gives a greater sectional area at the bottom, where the strain is greatest upon piles performing the duties required in that and similar works. Further advantages of having the butt down are that the piles have a much stronger hold in the bottom and present less surface to the current. Piles were driven to any depth desired up to 18 feet, although before reaching that depth the progress became very slow.

"Owing to the great quantities of gravel found in this locality the maximum depth reached here would be lower than the same plant would accomplish under more favorable circumstances. It is safe to say, however, that whenever the ascending current fails from any cause whatever to bring the material excavated up to the surface of the river bottom, the maximum depth to which that pile can be driven by the force acting upon it has been reached. The river would fill the space around the pile with the material composing its bottom, and pack it as soon as the upward flow was checked.

"The causes which might conspire to bring about this result are numerous, one of the most prominent being the collection around the foot of the pile of the heavy material through which it has passed."

E. H. BECKLER—PILES DRIVEN BUTTS DOWN.

I would refer here to a lack of success in driving piles butt downward by drop hammer only, at St. Louis River Bridge, near Duluth (Journal of the Association Engineering Societies, E. H. Beckler, 1886). Tests showed that the expense was more, even for a less depth. Besides this, the small end was considered liable to decay. There have been no great repairs made there on account of ice.

A pile sunk by the use of the jet is said to stand more pressure than one driven by hammer alone, as the sand about it is better compacted. (Journal Association Engineering Societies, Dec., 1881).

MAJ. HENRY A. GRAY—BORING MACHINE.

In certain soils it is possible to still further increase the efficiency of the jet by the use of revolving knives at the point. An account of this sort of machine and its successful use is given in *The Canadian Engineer*, April, 1895, by Major Henry A. Gray, Department of Public Works. He says:

"In 1893 extensive pile-driving was done as protective work when widening the River Sydenham at Owen Sound, to increase the harbor area. Previous work had shown the difficulty of driving piles through the sand and other compact material found there of sufficient length to allow the lower ends to be below the depth required to be dredged in the harbor. With the boring machine shown here rock elm piles 12x12 inches by 40 feet were put down full length in three minutes, perfectly perpendicular and in proper place, with a few light blows. Eighty to 100 piles 20 feet long have been driven in 10 hours.

"The machine consists of a shaft, to which a turbine about 5 inches in diameter and screw are fixed and contained in a cylindrical casing, supplied with water under pressure, and having openings arranged in such a manner that the water forced into said casing will, in escaping, act upwards against the soil loosened by the cutting blades fixed near the end of the shaft. These form a sort of two-blade propeller, forcing the earth, clay, etc., upwards. The machine is unsuited for a bottom where large stones are to be met with, and also, for obvious reasons, for pure sand."

The preceding collection of notes serves to give us a due respect for the subject and its uncertainties. The question of "prognosticating" is still before us. Would Sir Christopher Wren

himself consider that the work of "registering past times" had gone on far enough to warrant it?

I leave this question and the general subject for your consideration.

DISCUSSION.

Mr. George B. Francis.—I have been very much interested in listening to this paper, but in two or three respects my experience fails to coincide with the author's views. First, as to the point of "no set." With pile hammers of 1500 to 2000 pounds I have always found a "set" of 6, 8, 10 or 20 inches in 100 or more blows. In a great many instances we crushed the pile long before the point of no penetration is reached. I cannot see how these men, with hammers of 1500 or 2000 pounds, failed to get more set. My experience is that we should get about a foot of set on solid rock with this number of blows.

Very few of the authorities quoted say anything about crushing timber, and it is a very easy matter to crush it, especially if it is spruce or any timber except white oak.

Another point is that care enough is not used in writing about the safe load in tons per pile. One can read the articles of some of these writers for a long time without gaining the least idea of what kind of a pile is being talked of when the tons per pile are mentioned. Whether a pile is good for six tons or thirty tons depends upon the size, length, kind of timber and ground, and no offhand unqualified statement should be made of the general safe loads per pile.

The following notes are based *wholly* on my own experience, and it is with some diffidence that I pretend to say much, knowing full well that there are many others who have had a longer and better experience than myself:

The timbers that seem most suitable for piling in the territory in which I have been working are spruce, yellow pine, several varieties of white or other oak, and, in Oregon and California, fir. In diameter, spruce piles generally vary from 10 to 12 inches at the butt, and from 5 to 8 inches at the tip; and they can be obtained in any lengths up to 50 feet at reasonable rates.

Yellow pine piles vary from 12 to 20 inches in diameter at the butt, and from 6 to 8 inches at the tip, and can be obtained in lengths up to 80 feet. Oak piles generally vary from 12 to 15 inches at the butt and from 6 to 8 inches at the tip, and can be obtained in varying lengths up to about 55 feet. Piles from the Oregon fir vary from 16 to 26 inches at the butt and from 8 to 12 inches at the tip, and can be obtained in lengths up to 175 feet.

In this vicinity spruce piles, from 30 to 45 feet long, cost from $3 to $5 in place. Yellow pine piles, as long as 70 feet, cost nearer $15 each for the piles themselves, and $2 or more each for the driving. Oak piles, from 40 to 50 feet long, cost from $8 to $10 each in place.

Piles are used for a large number of purposes. The conditions in each case are usually different, and what will be a good specification for one place will not do at all for another place.

Piles are most commonly used as bearing piles, wharf piles, trestle piles, fender piles, batter piles, guide piles for ferry slips and as sheet piling for cofferdam purposes.

The ground conditions met with vary extremely. In some instances it is necessary that the pile shall act as a column descending through soft material to a very hard bottom. In other instances no reasonable length of pile will reach a hard bottom, and it is necessary to depend upon the friction of the ground upon the sides of the pile. These latter conditions predominate. Once in a while it is found necessary to shoe the points of the piles with metal; but, as a rule, if the ground is hard enough to require such treatment, it is also hard enough to support an ordinary structure without piles. In the case of a column, it is necessary to specify a pile which will be of large diameter at the tip. In the case of friction bearing this is less necessary. Sometimes piles in friction ground are placed too close together, so that the value of the friction is lost; but it is desirable to place them close enough to consolidate the softer material between them. In some trestle structures it is preferable to use oak piles; in others spruce piles. In the case of bearing piles for buildings, it is of course necessary to their preservation that they should be below the ground water level.

Of the large variety of pile-driving machines employed, some are for use upon the water, others on the land and others for cars for transportation upon railroads. In Boston the style known as "The Boston Roller Machine" is generally used; in other cities the swivel machine is frequently seen. The engine should have two drums, one for the purpose of hoisting the pile and the other for hoisting the hammer; and it should by all means have friction drums. The hammer is sometimes a heavy piece of oak, and at other times a long, slim piece of wood, for the purpose of driving piles in a trench, with the driving machine upon the surface of the ground. In Boston a few years ago a common hammer weighed from 1500 to 1800 pounds. At present they vary from 2000 to

2500 pounds. In the vicinity of New York hammers weighing 4000 pounds predominate. In other parts of the country hammers as heavy as 7000 pounds are used. In Chicago steam hammers are largely used, but they are not seen very frequently in the East. The hammer line is sometimes attached direct to the hammer, and at other times to an automatic clutch, which is detached from the hammer when the blow is struck. The former arrangement is vastly preferable for rapid and economical driving. As a rule, engineers' specifications require too much resistance before a pile is considered to be sufficiently well driven. My own experience is that with spruce piles, when the penetration is less than about 1 or $1\frac{1}{2}$ inch per blow, there is very serious danger of permanently crippling the pile, and that, although slighter penetrations are prescribed, the custom is to accept a penetration of 2 to 3 inches on the average. Very frequently a penetration of 8 inches or a foot is obtained at the last blow, and if the pile is allowed to stand for twenty-four hours only a fraction of an inch can be obtained under the same conditions.

In order to determine the proper lengths of piles, there are various methods of endeavoring to ascertain the character of the material through which they are expected to be driven. Sounding rods are sometimes forced into the ground, borings are sometimes made and test piles are driven. I consider the latter method preferable, if only one method is used, but should desire borings in addition if possible.

I consider the *Engineering News* formula the best formula for ascertaining the approximate supporting power of a pile. This is based upon the fall of the hammer, free from the hammer line, which, as above stated, is not customary; and allowance must be made for the friction of the rope while the hammer is descending.

Piles are shod with cast iron shoes, sheet iron points, steel points with welded straps and various other appliances. All these are generally unsatisfactory, the blow of the hammer being, in most instances, sufficient to very quickly detach any shoe. It is better in such instances to do without the pile altogether.

It is not wise to trust in the slightest to the value of pile foundations as a lateral support; in almost every instance where this is done the engineer will come to grief. The supporting power may be first-class, but the value for a side push is practically nothing.

Experience has satisfied me that piles should not be cut off with an axe after being driven. The best thing is an ordinary cross-cut saw, upon two straight edge guides attached to the piles,

whenever the cutting can be done in the open air. The next best thing is a circular saw upon a rigid support. If a circular saw is used from the leaders of a water pile-driver, the result will be most unsatisfactory without the closest kind of a watch; even with the cutting 2 feet under water, the grade of cut-off will vary at least 1 inch, after watching the work very carefully. In deep water the grade will vary several inches after doing the best that can be done.

Both square caps, drift-bolted to the heads of piles, and clamp caps, clamped to the heads of piles, are used for capping. The latter should be avoided if possible. In the case of pile foundations for retaining walls, where the capping comes below water level, it is better not to try to bring the piles into line and cap them, but to sink a solid platform, made of at least three courses of timber. In this case the platform will rest upon all piles and upon the entire head of each pile. These courses of timber may vary in thickness to suit the circumstances.

For retaining walls and sea walls, as well as for bridge abutments, it is absolutely necessary that there should be an ample quantity of rip-rap, or bracing of some sort, against the heads of the piles to resist lateral pressure. Usually insufficient rip-rap is placed, and a movement takes place, greatly disfiguring the walls.

In the case of pile trestles, first-class sway bracing is absolutely necessary. In some of the older work in New England it was customary to omit the sway bracing and to put in, between the bents, what is known as lateral bracing, just under the floor, similar to the lateral bracing in the panels of an ordinary bridge. The sway bracing will not only accomplish the same result, but immensely stiffen the work.

Where exposed to the ravages of sea worms, it is necessary to protect piles by creosoting them, or by covering them with some substance to shut out the worms. This is sometimes done with ordinary vitrified pipe, slipped over the heads of the piles, the intervening space being filled with cement mortar. In some instances the piles are coppered. I know of one place where the piles were driven full of small shingle or lath nails, driven so close together that it was impossible for the worms to get in between the nails.

I do not believe in sharpening the points of piles before driving, but think pains should be taken to have the tips cut square to the axis of the pile. I have frequently seen piles cut off to grade before adjacent piles are driven, and afterwards, when driving the latter, have seen the piles rise from 2 to 3 inches, showing that the ground between the piles is thoroughly compacted, and that there

is no room for it to move except in a vertical direction, which is the line of least resistance.

The proper load for piles is frequently discussed, and sometimes without any reference to the kind of pile or the conditions at hand. If a large oak pile is used, perhaps it would be safe to assume that it will carry 15 or 16 tons—perhaps sometimes as high as 20 tons; but if small piles are used it is sometimes wise to restrict the load to as little as 6 tons. A hard and fast rule should not be laid down.

In calculating the load on piles used under railroad bridge abutments there is much divergence of views. Some calculate the dead load of the masonry that is to be carried, while others include the train loads and the weight of the bridges. In pier work, buried underground, it is hardly ever considered that the pier takes a considerable load from the surrounding earth. All these matters must be carefully thought of before assuming the proper load for the piles.

Once in a while it becomes necessary to use what is known as a follower, but I have never yet seen a follower that gave very satisfactory results. I always avoid them wherever possible.

Some specifications require that the bark shall be stripped from the piles. Except in a few instances, I do not think this is of much consequence one way or the other. It is better, if possible, to avoid the expense.

The following instances of pile-driving, in work with which I have been connected, may be of interest:

In Portland, Oregon, it was necessary at one time to build trestle approaches on each bank of the Willimette River, for the purpose of transferring cars from the railroad to the ferryboat. The range of high and low water in this instance was about 30 feet. The trestle inclines had to be built to cover this range. They were built at a time when the water was about at a mid stage. The slope of the banks toward the channel was about 45°, and consisted of hard pan, or cemented gravel. It was not possible, with the time and facilities at hand, to build masonry upon this hard pan. The trestle inclines were necessarily pile structures, and it was impossible to drive the piles upon one side of the river into the cemented gravel or hard pan. Cast iron pot shoes were made, weighing some 200 pounds each, if I remember rightly. These were fastened to the points of the piles, and in the bottom of the shoe there was placed a steel spike about 2 inches in diameter and 2 feet long. The only part of this pile that was expected we could get into the ground was the steel spike; and, as soon as the

steel spike was in the hard pan, it was necessary to fasten the pile temporarily, so that it would remain in position before the pile-driver let go of it. These inclines were thus built and served their purpose for several years. The foregoing is a condition not usually met with.

At the Thames River Bridge, in New London, one of the piers, supported by piles, settled. The weight per pile was about 19 tons. These were spruce piles of ordinary lengths, driven into mud, sand and gravel; and, according to the inspector's book, were driven to "absolute resistance." The pier, however, settled about 15 inches, piles and all, and was stopped only by transferring some of the load to additional piles driven around the pier, reducing the load per pile to about 13 tons.

On the Jersey Junction Railroad, at Newark avenue, Jersey City, as engineer in charge, I had occasion to drive some piles into the surface of the street to support temporarily a large water pipe, afterwards excavating the street for the passage of a railroad beneath it. The piles were well driven, and supposed to be in good shape. The supports for the water pipe were placed, and the street was dug out. It was found that about half of these piles were ruined in the driving; some were broken off square and the butt driven down alongside of the tips. One pile in particular encountered a large flat rock about 16 feet under ground, but the pile was supposed to have been driven properly. When this rock was reached it was found that the fibers of this pile were anywhere within 15 feet of it, off in a horizontal direction.

Another instance of a similar character occurred at Atwell's avenue railroad bridge, Providence, where a number of spruce piles were driven into ordinary sand, to carry a temporary bridge while excavation should be made for the passage of the railroad beneath. The result was similar to that in the Newark avenue incident.

At another point in Providence, where piles were driven for temporary support for railroad tracks over a sewer trench, it was found impossible to drive black oak piles with any satisfaction. The sticks were so irregular in shape and so covered with knots that the ordinary machine would not drive them into the ground. Spruce piles were substituted, and carefully selected for their straightness and smoothness, and these were driven where it was impossible to drive the oak piles.

It is quite probable that if we could excavate around all the piles that have been driven in Boston within the last two years we should be utterly surprised at the appearance of the sticks. I

doubt not that many of them would be found to be broken, crushed and far different from what is usually expected.

Upon the Ulster division of the West Shore Railroad we had a specification which called for something like $\frac{1}{2}$-inch penetration at the last blow. Piles were driven under this specification, and the penetration was nearer a foot at the last blow. The next day the pile-driving machine was placed over the piles, and the penetration on the first one or two blows was within the limit of the specifications; consequently the contractor held that the pile-driving was within the limits of the specifications, and he was sustained.

At another point, called "Crumb Elbow," I had occasion to take some rod soundings to ascertain the proper length of piles to order for a trestle across a mud cove. We had eight men in the party, but, owing to the stiff nature of the mud, which was really clay, we were unable to penetrate with the sounding rod exceeding 7 feet with our utmost endeavors, and concluded to send the pile-driver and drive test piles. In the same spot we found no difficulty in driving 70-foot piles into this clay. Ever since that experience I have not had much faith in rod soundings.

Upon one piece of work, where a steam hammer was used, we found that the heads of the piles were not quite large enough, and that they worked up into a ring, through which the plunger of the hammer descended. To avoid difficulty the workmen cut off small planks and laid them on the head of the pile, and went on with the work; but it was soon discovered that these small blocks of wood were ground up under the blow of the hammer and driven right into the middle of the head of the pile, frequently splitting the pile for some distance down. This practice had to be abandoned.

As piles are usually delivered upon the work, the heads are beveled just as they come from the forest. I have noticed that, to avoid too much sawing, contractors will sometimes cut off just a little of the head and hammer about one-quarter of the area of the whole pile, sometimes forcing this small area right down into the head of the pile, splitting the pile as above described.

In the foundations of the Providence Passenger Station, and the accompanying bridges, we used about 17,000 piles. This is a friction ground, and the piles were of spruce, averaging about 45 feet in length. At the river bridge we drove a large number of batter piles, and after many trials concluded that we could not drive batter piles with a greater inclination than 3 inches per foot

out of the vertical with any satisfaction. Some of these piles were driven with a steam hammer and some in the ordinary way.

At the Harbor Junction pier of the New Haven road, in Providence harbor, we placed a foundation for a coal pocket upon yellow pine piles about 70 feet in length, which piles settled with the weight only of a 4000-pound hammer about 30 feet into the mud for a start, and the remaining distance 4 and 5 feet at a blow, the hammer falling a very moderate distance; as I remember it, not much more than 6 feet. Trying these piles the following day proved that the penetration was within the ordinary limits, and the coal pockets were built upon them; and they have never given any trouble.

At the Wilkesbarre pier, at Providence harbor, where another coal pocket was constructed, we felt safe in cutting the piles off at half tide, believing that they were protected against decay by the constant wetting of the rise and fall of the tide. At this same place there was timber that had been in use twenty years, with no evidence of decay when placed at the same height. The range of the tide at this place is about 5 feet.

At the new Southern Station in Boston there will be used about 44,000 spruce piles for bearing piles, and about 5000 sheet piles. This is a friction ground, and piles are ordinary spruce material, ranging from 25 to 45 feet in length. In this instance we loaded three piles, for a test, with 60 tons of pig iron, amounting to about 20 tons per pile, with no resulting settlement. I have a photograph here of the piles with their load of pig iron; should have put on more, but we got the iron so high we were afraid it would fall over. The specified loading was 10 tons per pile. In this work there has been some night work on pile-driving, but my advice is to avoid it if possible. It is dangerous work.

I have had a great deal of trouble in forcing foremen to keep the machines and leaders plumb. It makes an immense difference in driving the pile, and we have had to be continually after them to plumb up the leaders.

Hardly a day passes but some one rushes into the office and states that in a certain place we are driving the piles too deep; that we have got through a hard stratum into a poor stratum, forgetting that in friction ground what we are after is a good deal of friction.

From my experience I feel justified in saying that no hard and fast rules can properly be laid down for procedure, but that each new job requires a study of its conditions, and a ruling to suit those conditions.

Mr. S. E. Tinkham.—During the past year there have been

driven about 4000 piles for the foundation of the sea wall which the city of Boston is building in Fort Point Channel, near the new South Union Terminal Station; and, as the material here is a soft clay, we have been obliged to content ourselves with a penetration, at the last blow of the hammer, so much greater than any mentioned in the paper that it may be of interest.

The material which we found at this point is a soft blue clay, changing in a few instances to a soft yellowish clay, and extends to a considerable depth. A series of borings, made along the line of the proposed wall to a depth of 65 feet below mean low water, failed to show any other material. I understand that just across the channel, not more than 1000 feet away, the same material was found to extend to a greater depth than 170 feet below mean low water. With material of this nature we must depend almost entirely upon the increased friction which is developed after the pile is allowed to rest, and can derive very little assistance from any formula based on experiments which gave final penetrations of one-half inch or an inch.

In the work to which I have alluded spruce piles were used not less than 7 inches in diameter at the point, and at least 9 inches in diameter at the butt; they varied in length from 35 to 55 feet, according to the stiffness of the clay in which they were driven and the load they were intended to carry. The driver used was mounted on a scow and had a hammer weighing 2300 pounds, the rope or fall being attached to the hammer. Under these conditions the total maximum penetration allowed for the last five blows, with a fall of the hammer of 8 feet, was 24 inches.

Some experiments were made to see how much the resistance would be increased by allowing the pile to rest for three or four days, and I can give one or two illustrations which may be of interest:

A spruce pile, 35 feet long, 7 inches in diameter at the point and 10 inches at the butt, was driven 20 feet into the clay with a 2360-pound hammer falling 8 feet. The total penetration for the last five blows was $27\frac{1}{2}$ inches. After a rest of four days the pile was struck twenty blows with the same hammer, falling the same distance as before, and the result was a total penetration, for each set of five blows, as follows: First set $4\frac{1}{2}$ inches, second set $7\frac{1}{2}$ inches, third set $9\frac{1}{2}$ inches and fourth set $7\frac{1}{2}$ inches. The average penetration for each of the twenty blows was almost exactly $1\frac{1}{2}$ inches, as against a penetration of $5\frac{1}{2}$ inches per blow at the end of the first driving.

A second pile, of the same dimensions as the first, was driven

in material slightly softer, the hammer and fall being as before. The total penetration for the last five blows was 38 inches. After a rest of four days the pile was struck fifteen blows, and the total penetration was found to be, for each set of five blows, as follows: First set 8 inches, second set $8\frac{1}{2}$ inches and third set $8\frac{1}{2}$ inches, or an average of $1\frac{2}{3}$ inches for each of the fifteen blows, as against over $7\frac{1}{2}$ inches per blow at the end of the first driving.

Mr. James W. Rollins, Jr.—If some of the piles which engineers think so well driven could be pulled out, I think their condition would be such as to materially change such a conclusion.

We are at the present time driving piles for foundations for masonry—in the Back Bay district, on Ipswich street, Boston—and the results of this work have satisfied me that while piles are apparently going down under hard driving, they may be either crippled or broomed up, so as entirely to lose their efficiency.

We drove the piles, some 360, for the foundations of a bridge across Stony Brook, using 30 to 35 foot piles, driving them down to grade — 30; one pile, an average one, going down, under thirteen blows of a 2000-pound hammer, in 40 seconds.

We then started on the foundations for a highway bridge under Charlesgate East, about 300 feet west from the bridge at Stony Brook above referred to. The abutment was L-shaped, and we started in the end of the wing, piles being driven to saw off at grade 5; and material being, as shown by borings taken later, about 10 feet of coarse gravel filling; then 25 feet of silt and sand, and a natural bottom of gravel at grade — 30. The piles were spaced 2 feet on centers each way, and the first row at end of wing went quite decently, being good, fair driving.

Very soon difficulty developed in trying to get the piles down through the gravel filling. A pounding of 100 blows by a 2300-pound hammer would only get the *head* down a foot. We then tried a water jet, and under a pressure of 260 pounds to the square inch on the jet, through a 1-inch gas pipe fastened to the pile, we had no better success, it being impossible to keep the jet in place while pounding through the gravel. Meanwhile we had shod the piles with a cast iron point, held in place by a $\frac{7}{8}$-inch iron dowel 15 inches long.

After consultation with the city engineer, he wished us to try in another place and find whether bottom was uniformly hard, in which case he proposed to abandon the piles and "float" the masonry on the gravel filling.

At this stage two soundings were taken, and both proved the material to be as previously stated, 10 feet of gravel overlying a

soft stratum. This gravel filling had been in about fifteen years, and had been under a pressure of 30 feet of filling above the bottom of our excavation.

We moved our driver and began at junction of center line of wing and main wall, at the point where the sounding was taken. The first pile driven went all right, and we thought our trouble ended and continued on main abutment on outside row. In a day or two we found the same difficulty, and concluded to experiment a little. According to theory and the soundings, the piles should go easily after getting through the 10 feet of gravel, and we so concluded that if the pile continued to drive hard after this distance something must have happened to the pile.

We drove a pile 12 or 15 feet into the bottom, it still going hard, and then pulled it out, finding it crippled with a broom 3 feet in length at end. Another pile did the same thing, and a third, after driving hard down 15 feet, suddenly went easier. On being pulled it showed another cripple, without the broom. The piles were of spruce, and 35 feet to 40 feet long.

These experiments proved that it was impossible to drive piles into that gravel when spaced 2 feet on centers, so the engineers told us to try to drive half of them. We tried this plan, and got ahead quite well until we approached the other piles previously driven with an area of 10 x 16 feet between the two bunches of piles. We were then unable to get a single pile down without crippling in the gravel. One pile was pounded down with 1300 blows, one foot taking 357 blows, and three consecutive feet over 700 blows; but our opinion is that its foot is spread out somewhere through the silt, and nowhere near the hard bottom the engineers were after. We then put in the middle of main wall a new machine with a 2700-pound hammer, and went ahead with no trouble, on half space driving, until we approached the piles in the wing, and here again we found the same trouble and could not get the piles down. Of eleven consecutive piles tried, we drove one on outside row down, and drove and pulled the other ten, finding nine of them crippled, the piles being driven only 5 feet into gravel and driving being stopped on first evidence of trouble, which showed itself in the springing of a pile under the blows and even under the rebound of the hammer.

One pile, being selected as the best of the stock on hand, was tried in the same hole where two had previously been driven and pulled out, and under blows of only 2 or 3 feet drop of hammer (such blows taking 60 to drive the pile one foot) crippled in 5 feet of driving. In this one place we tried four piles, and could not get

one through the gravel. This same place was within 4 feet of one of the borings.

This experience has shown that, in certain kinds of material, it is impossible to drive piles 2 feet on centers; also that while the head of a pile may go down, it does not follow that the bottom is going equally far.

Experiences on railroad work, where piles were driven to carry the tracks while a road was cut through under them, has shown the same results; that while the piles have been driven into the ground under very hard pounding, they have been crippled or

smashed to pieces by this pounding, and no good has been derived from them for supports.

At Brockton, in an effort to do work of this kind, we used very heavy oak piles, and managed, after pounding each pile some four or five hours, to get it down. The material was sand, and on excavating we found the piles all solid, but showing signs of hard wear.

This latter is the only case in my experience where piles have been driven into natural ground, for supporting tracks, and have kept their shape; and this I think due to the kind of pile used.

When a pile requires several blows of any hammer of decent weight to drive it a quarter of an inch, I do not believe that such a movement means any actual movement of the bottom of the pile, but more a crippling or compression of the timber.

The accompanying photograph shows some of the piles driven at Ipswich street, under Charlesgate West, and pulled out after having been driven as long as the piles "stood up." One shows the beginning of the crippling process, it having the shoe still on.

Mr. Frank W. Hodgdon.—The cases cited by the previous speakers were mostly of hard driving. I have in mind a case where, in building Pier No. 4 for the New York and New England Railroad Company, the spruce piles for the foundation of a part of the sea wall were driven through a considerable depth of soft mud into a soft clay such as Mr. Tinkham found in Fort Point Channel. The piles drove so easily that the contractors drove many of them just as they came from the woods, no attempt being made to square the ends. Notwithstanding the soft bottom, into which the piles penetrated at least a foot at the last blow, the sea wall has shown no apparent signs of settlement, although a large storage shed has been built on the pier and has been filled with heavy goods at various times for a number of years.

While I was discussing the question of pile-driving with an old contractor a few years ago, he told me that while building bridges on what is now the Boston and Maine Railroad, near Conway Junction, at one point they found the mud so deep that although the longest piles obtainable (some 60 to 70 feet long) were used, yet the penetration at the last blow was 2 feet or more, and he anticipated that the bridge would settle badly when the trains began to run; yet, although he visited and examined the bridge at least once a year for a number of years, he found no evidence of settlement. On the other hand, in many cases he had driven piles into sand where it was very difficult to drive them, they going only a fraction of an inch at the last blow, and yet the shaking caused by the passage of trains over the bridge caused the piles to penetrate further and the bridge to settle.

On the south shore of Massachusetts, and along Vineyard and Nantucket Sounds, the use of the water jet to drive piles is very common, both for wharf piles and for the Fish Weir poles. Formerly these were driven by a hammer running in guides, but now the pile is stood up in position and water is pumped through a small pipe ahead of the point of the pile, forcing the sand aside, and allowing the pile to settle into the bottom, either by its own weight or by the addition of a weight placed on top of the pile.

In this way the pile can be placed exactly in the required position, and is controlled much better than when driven by a hammer. This process cannot be used in gravel or coarse material, as the water will wash out the finer portion, leaving the stones in the hole.

I wish to emphasize the fact, stated by Mr. Francis, that no dependence should be placed on a pile foundation to resist any lateral forces. In building a sea wall in 1888 on the South Boston Flats, the foundation piles were driven through 10 to 18 feet of soft mud and 15 to 18 feet into the clay beneath. Around the heads of the piles, for a depth of 3 to 4 feet, was placed broken stone ballast, and a spur pile was driven between the main piles every 7½ feet to stiffen the foundation. Notwithstanding this, when the mud and clay filling was placed back of the wall, a section of the wall moved forward, the greatest movement being about 2 feet. The wall itself moved out bodily, the foundation piles probably bending forward through the soft mud, the spur pile being forced slightly deeper into the clay. In order to avoid such movements in the walls we are now building the mud and fine sand are excavated to the depth of 15 to 20 feet below mean low water, and the space around the piles and sloping out in front of the wall is filled with coarse gravel, and the exposed slope is covered with a layer of broken stone rip-rap on a slope of 1½ to 1, this slope of 50 feet from the face of the wall to deep water in the dock or slip being covered by a pile platform or wharf, alongside of which the vessels are made fast. This pile of gravel holds the piles in place and gives the necessary lateral strength to the foundation of the wall, the piles simply supporting the vertical pressure of the wall and preventing its settlement.

Our piles are driven at least 15 feet into the soft clay, it taking three to four blows of a hammer weighing about 2000 pounds falling 6 to 12 feet to drive them the last foot. When these are first driven the heads are readily swayed as much as 2 feet, with about 15 to 20 feet of the pile projecting above the material into which they are driven; but at the end of a week it requires considerable force to move them. When trying to remove guide piles which have been driven two or three weeks, and to a depth of only 5 or 6 feet into the clay, they have frequently broken before they could be pulled out. The tenacity with which clay clings to a pile increases with the length of time the pile has been driven. This was well illustrated by a bulkhead which was built to retain filling on South Boston Flats. The bulkhead consisted of a row of spruce piles driven 6 feet on centers planked up on one side and supported by two spur-shores on the other. Both main piles and

spur-shores were driven about 12 feet into the clay. The main portion of the bulkhead was built about three years before the filling was placed against it. A gap was left for the passage of scows, and this gap was closed about two months before the filling was placed against it. When the filling was being done the older portion of the bulkhead held its position, but the newer part was pressed out; and the main piles were partially pulled up by the straightening up of the spur piles, the clay not having had time to become so firmly attached to them as it had to the piles of the older portion.

Mr. Carson.—In the case of the wall which moved out 2 feet under pressure from behind, what offered the resistance that caused it to stop at 2 feet?

Mr. Hodgdon.—The spur piles were forced into the clay, and the forward movement of the wall must have compacted the material ahead of it to a certain extent. The further ahead it went the more resistance it had to overcome, and the material in the rear had a chance to dry out and set and so exert less pressure.

Mr. Carson.—As to piles having power to resist lateral pressure, you mean vertical piles?

Mr. Hodgdon.—Yes.

Mr Sidney Smith.—I am reminded of some soundings made with a $\frac{5}{8}$-inch rod of iron for a railway pile bridge over the Black River, at Holland, Mich., in 1872. The different materials thus found were platted on a profile, to enable the chief engineer, Mr. Wm. A. Haven, to estimate the lengths of piles required. Subsequently the average penetration of the four piles in each bent were platted upon the same profile. The depths to which these piles were driven indicate that a good estimate of required lengths may be made by this method, for they followed closely the depths of the soundings. When better and more expensive methods are not available to test the materials to be penetrated, a very useful study may be made by sounding with a common iron rod.

At another railroad pile bridge 40-foot piles were driven where 6 to 12 inches was a common set. In one bent the first pile drove very hard, the second easily and the third with very few blows. For the fourth a 45-foot pile settled into place without a blow. It was lengthened by splicing another pile to it, and the combined length penetrated the mud about 80 feet under the weight of an 1800-pound hammer. That was the last work done that day. The next morning the chief engineer was present, when this pile received several blows with a fall of 16 feet, which failed to start it.

In a portion of the covered channel of Stony Brook, in Boston, built in 1888, the timber platform supports two arches of masonry, each 12.5 x 12 feet, with their contents and a paved roadway, whose surface is about 4 feet above the crowns of the arches. Borings had been made there with the improved appliances in 1887, some of them showing mud or very soft clay 83 feet or more below the platform. As pile-driving progressed, it was observed that those first driven would rise. Therefore the bents were not capped until the piles were in place about 20 feet ahead. At this distance the upward movement had ceased. No subsequent settlement of the structure has been noted.

Mr. Rudolph Hering (by letter).—The paper of Mr. Howe, which he has asked me to discuss, is valuable for the collection of data and opinions of experts which it contains. These data and opinions, although partly published elsewhere, were scattered, and, to the busy engineer, it is a great help to find them collated for easy reference. It would, of course, have been still more valuable had he taken the further trouble of segregating the isolated facts, so that it would have been more convenient to apply them to new cases, and so that the relative value of the data to the case in hand could be more readily appreciated.

It has appeared to me that we should treat the subject of the strength of bearing piles similarly to that of the strength of beams. That is to say, we have, for the latter, first, a mathematical expression or formula for the translation of forces, which are due to the form and dimensions of the structural elements, and to the character of loading and support. Then, to reach the practical from the theoretical case, we introduce into the formula numerical coefficients, including the factors of safety, which are determined by experiment or general experience, for the particular materials used, and for the future exigencies arising from the location of the structure or from its intended use.

Proceeding in the same manner with piles, we should first have the mathematical expression which deduces the bearing power from the frictional support given the pile by the material surrounding it, and then have the coefficient which determines the degree of friction for the particular materials ascertained by experiment; and allow for the future exigencies arising both from the nature of the soil into which the piles are driven and from the magnitude and frequency of the vibrations to which the structure resting upon the piles will be subjected.

The difficulty we meet with here lies in the determination of such a coefficient within reasonably close limits. In the case of a

beam we have certain well-known materials of uniform texture, for each of which numerical values have been ascertained with a fair degree of accuracy, and we can nearly always safely apply them for a new structure. But in the case of a pile the material into which it is driven is of great variety in its sustaining power, and is often known to us only in a general way as being sand, clay, loam, muck, etc. We have, further, the element of time, namely, the changes taking place in the degree of compactness with which the material settles around the pile, sometimes increasing and sometimes reducing the original friction. It has therefore been customary to provide for all these unknown elements by assuming large factors of safety.

Engineering science is constantly seeking to diminish the extent of the realm of the unknown, and practical business men, in competition with each other, are seeking to get the best results with the least expenditure of money. Therefore, in engineering structures the factor of safety, otherwise called the factor of ignorance, is being constantly and properly reduced. How can it be reduced in the bearing power of piles?

In my own opinion it can be reduced only by the use of test piles driven on the site, which expedient is equivalent to taking, in the case of beams or small structures, the published experimental data for their breaking strain under well-known similar conditions to those of the new structure. The driving of test piles between periods of rest, and from the result ascertaining the actual and safe sustaining power of the soil in question, is justified because the material into which the piles are driven may vary considerably from that upon which our previous experience was based. In every important case, and for safety and economy, I consider that the true frictional resistance and the degree of its continuity should be directly ascertained by driving test piles repeatedly after periods of rest.

Professor Kreuter, in a paper on this subject (see Proc. Inst. C. E., Vol. CXXIV, pp. 273), which is alluded to by the Author, mentions the defects of the formulæ hitherto proposed, in ignoring the true effect of elasticity and weight of the pile, and suggests a way of utilizing to the best advantage the results derived from test piles. It is practicable by this method to eliminate many of the uncertainties due not only to the pile itself, but also to the material into which it is driven. In addition to the precautions quoted by the Author, regarding the allowance of time for rest after driving, and with regard to the maintenance of a sound and solid surface to receive the blows, Professor Kreuter later added, in an adden-

dum, the further important precaution that the heights from which the hammer shall fall in the testing sets of blows must not be widely different from each other, and must be as near as practicable to the height under which the hammer no longer does any useful work. Experience will have to demonstrate how far Professor Kreuter's method is practicable. In any case, it seems to be a move in the right direction.

Spencer Cosby, First Lieutenant U. S. Engineers (by letter). —In 1895 we had occasion to drive over 4000 piles inside the walls of Fort Delaware, and I made an effort then to ascertain whether any further settlement had taken place in the walls of the fort since the date (1868) of Major Delafield's paper. I could, however, find nothing in our records in regard to this matter, nor could I ascertain the location of the old bench marks. To the best of my belief, however, there has been no perceptible settlement since the average of 3.19 inches recorded by Major Delafield.

The fort stands with a single small unimportant crack in one casemate arch. No other evidence of settlement has anywhere been observed.

We made attempts to pull up two of the old Sanders piles. One resisted an estimated pull of 60 tons; the other broke off at the point where the chain was fastened, 3 or 4 feet below the head. In making our excavation for the new work we came across a number of Sanders piles, as well as others, driven, it is believed, by Major Delafield between 1834 and 1838. All exhibited the same characteristics. The wood was thoroughly water-soaked and soft; the outer layers of sap were decayed, often for several inches in from the surface. The heart seldom, if ever, appeared to be affected, and the decay extended less and less deeply into the wood below the water line, and seemed to disappear entirely within 5 or 6 feet of it. The piles were so soft, and crushed so easily, that it was found impossible to apply any test to them by re-driving.

Prof. W. M. Patton (by letter).—I have not been able to examine the paper with that degree of care to which its value and importance entitle it. I have, however, read it over carefully, and have been very much interested in it.

You, of course, understand my position on this matter, which, simply stated, is that there is not and cannot be any kind of relation existing between weight of hammer and height of fall and the bearing power of a pile.

By this I do not mean that I am disposed to discard all formulæ, but simply that, while I may use such formulæ, I have little confidence in their reliability; and, in the absence of some

precedent, I should regard nothing of value except direct experiment.

It is very probable that, in driving piles in compact sand and gravel, we are entirely deceived in regard to penetrations unless the jet is used. I know of piles which have been battered and crushed at the point from 1 to 2 feet after hard driving.

My understanding as to the foundation of the New Orleans Custom House is that it is simply built on a grillage, or platform of timber. I may be mistaken, however.

Horace J. Howe.—I was quite well aware that it was advisable for some one to draw conclusions or progress statements, as suggested by Mr. Hering; and I consider that it is much more advisable now, in the light of the able discussion we have had.

At this stage of the reader's patience, however, it is impossible to do more than emphasize a few points:

First.—(a) That a single test pile, when driven separately and apart, and loaded with an ultimate load, is inadequate. (b) That a single test pile in a cluster, loaded with an ultimate load, is inadequate. (c) That a test is accurately adequate only when it fulfills all of the subsequent conditions of loading, and is made over a sufficient area and for a sufficient period of time.

Second.—That a pile frequently crushes at the bottom in hard driving, misleading at times the most experienced inspector; and that any calculation, in terms of set of pile, would be thereby rendered useless.

Third.—That with piles not subject to vibrations the bearing power increases after driving up to a maximum, and that this maximum does not decrease with time, *provided* that there is no easing of the foundation as a whole internally by water, or externally by neighboring deformations in the soil.

Fourth.—That piles resist pressure reliably only along their length, and not laterally, for any length of time.

ASSOCIATION
OF
ENGINEERING SOCIETIES.

Organized 1881.

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ADDRESS BEFORE THE MONTANA SOCIETY OF ENGINEERS.

BY C. W. GOODALE, RETIRING PRESIDENT.

[Eleventh Annual Meeting, Butte, Montana.*]

THE Montana Society of Civil Engineers was instituted July 5, 1887, with 48 charter members, and the first annual meeting was held January 21, 1888. The organization has therefore just completed its tenth full year. Since our last annual meeting the name of the Society has been changed by the omission of the word "Civil," thus making the requirements for membership less exclusive, and increasing our numbers from other engineering professions.

The Society has gone steadily forward, and now has 112 names on its list of members, 32 enrollments having been made during the past year.

A review of engineering progress throughout the world may be expected of the President at the annual meeting, according to the strict interpretation of the constitution, but I find myself unable to do more than mention some work of this character which has been undertaken or completed in our own State.

NORTHERN PACIFIC RAILWAY.

Mr. E. H. McHenry, chief engineer, has kindly given the following very complete information regarding the work under his supervision:

*Manuscript received April 6, 1898.—Secretary, Ass'n of Eng. Socs.

Improvements completed by the Northern Pacific Railway Company, in Montana, during the year ending June 30, 1897.

New Steel Bridges.	With concrete piers and abutments.
Powder River	2-155′ Through pin spans.
	2- 70′ Deck plate girders.
Big Horn River	3-155′ Through pin spans.
2nd Crossing of Yellowstone River	3-155′ Through pin spans.
	1- 56′ Deck plate girder.
West Gallatin River	2- 75′ Through plate girders.
	2- 70′ T. P. trusses.
Thompson River	1-155′ Through pin span.
Cabin Creek	2- 75′ Deck plate girders.
Cedar Creek	2- 85′ Deck plate lattice girders.
Rosebud River	1-100′ Through plate lattice girders.
Pryor Creek	1- 85′ Through plate lattice girders.
Tongue River	2-155′ Pin connected through truss.
3rd Crossing of Yellowstone River	1- 56′ Deck plate girder.
	2-155′ Pin connected through truss.
Big Blackfoot River	1-160′ Pin connected deck truss.
	4- 50′ Through plate girders.
	2- 31′ Through plate girders.
	Six towers.

Roadbed and Track.—Old 56-pound steel rails in track replaced by a new rail of 66-pound and 72-pound section, 164.67 miles. Ballasting 65.5 miles.

In addition to the above the alignment has been retraced over all sections where steel has been renewed, and easement curves provided on all curves of 30° and over. Many minor revisions of alignment were made, and sags were filled or provided with vertical curves. The bank was widened from 14 feet to 16 feet at all points where new steel was laid.

Grade Revisions. The maximum grades on the first district of the Yellowstone Division have been partially reduced from 1 per cent. maximum to 0.4 per cent. by the completion of the revision at Iron Bluff.

The 1 per cent. grades on the first district of the Rocky Mountain Division have been reduced to 0.6 per cent. incidentally in connection with bank widening and ballasting.

The grade reduction on the first district of the Yellowstone increased the tonnage rating of trains from 625 to 900 tons, and on the second district from 625 to 1100 tons.

The former grade reductions and changes in operation on the Montana Division resulted in increasing the tonnage rating on the first district from 675 to 1000 tons, and the second district from 375 to 1000 tons.

The first district of the Rocky Mountain Division is as yet uncompleted. On the second district the grade reduction and improvements in operation have raised the tonnage rating from 400 to 1000 tons.

Tunnels. The temporary lining in the Bozeman tunnel has been replaced with a permanent lining of concrete and brick, concrete being used in the side walls and from 3 to 6 rings of brick in the arch. We have also tried the experiment of a concrete arch, which thus far seems to be an entire success, and effects a material saving in cost. The cost of completed tunnel with brick arch was $32.33 per lineal foot, with a concrete arch $28.43 per lineal foot. This is believed to be the lowest record extant. Similar work in progress on the Mullan Tunnel was completed during the fiscal year, the total cost of which was $165,899.

Yellowstone Dykes. Spur dykes were constructed opposite Iron Bluff, on the Yellowstone River, for the purpose of preventing the further movement of the sliding bluff at that point, thus far with entirely satisfactory results. The areas between the dykes have silted up, and several million yards of material deposited in the side channel. By a continuance of this work, it is expected to turn the entire water into the main channel.

The work of filling three large gulches on the Rocky Mountain Division, at Rattlesnake, Anheuser and Granite has been continued, and it is expected to have the present trestles replaced by embankment next year. Authority was obtained for the extension of the short branch line now in operation from Whitehall to the new Parrot Smelter, a further distance of 22.5 miles to Twin Bridges. The roadbed is completed for a distance of 17 miles to a point 6 miles north of Twin Bridges. Ten and a half miles of track have been laid to date. Further work will be deferred until next spring. Preliminary surveys and location have been completed from Rockvale, on the Rocky Fork Branch, to the Gebo coal mines, a distance of 12 miles, and preliminary surveys have been extended much further up the Clark's Fork Valley.

The result of the operations of the current year, in addition to that of previous years, has resulted in greatly improving the physical condition of our property. It is expected to further continue the work of grade reductions, replacement of timber bridges by new steel bridges and relining of tunnels until the line is in the best possible physical condition, requiring the minimum expenditure of maintenance.

GREAT NORTHERN RAILWAY.

Mr. John C. Patterson, engineer in charge of maintenance of way on the Montana Central, describes the work on that line as follows:

The most important improvement of the year has been the

continuation of the work of filling the wooden trestles between Clancy and Butte. To do this two steam shovels were engaged the entire season, and part of the time three were at work. They handled nearly half a million cubic yards from the pits to the embankments. In addition, between the same points, 17 steel bridges were erected over the Boulder River and other streams, replacing timber structures. For this latter work there were built 2440 cubic yards of heavy granite rubble masonry foundations, 182 cubic yards of concrete and 40 cubic yards of cut stone masonry, requiring 816 barrels of Portland cement and 1093 barrels of Louisville. The spans for these bridges consisted of deck and through girders of various lengths from 40 to 80 feet, the total weight of steel work being 494 tons. The locations of these bridges were distributed over about 17 miles of track, and the entire work, from the time of commencing the excavation for foundations of the first bridge, was completed in 3 months and 10 days, with no interruption to traffic. Thus our entire line from Clancy to Butte is now free from wooden bridges, with a few small exceptions which have been otherwise provided for, the old structures having been replaced by solid embankments and steel. One of the principal objects in carrying forward this improvement so rapidly has been to provide for use of heavier engines in the freight service. Two of these engines have been constructed and are expected in a few days. They are considered the largest locomotives ever built, weighing 172,000 pounds on the drivers, and having a total weight, engine and tender, of 308,000 pounds. As a comparison, these engines weigh 40,000 pounds more on drivers, and a total of 66,000 pounds in excess of the heaviest engines now in use on the line, from which an idea of their enormous size can be obtained.

For the more rapid and economical handling of engines at terminals and coaling stations, new coal chutes have been built at Great Falls and Wolf Creek, the one at Clancy has been rebuilt and a new one is now building at Teton. These are mentioned as they are believed to be a new departure in the means of handling coal quickly and cheaply.

It has been my intention to work up and present a paper before the Society describing these chutes, but, like many other good intentions, the matter has been laid aside for more leisure. In brief, the coal is elevated in the original railroad car to a height sufficient to allow it to be dumped into pockets, and from these by gravity into the engine tenders. The power is furnished by gasoline engines. This, I think, is the first introduction into this State

on a somewhat extensive scale of this economical power, and a somewhat inconsistent one, too, at first thought, when the abundance of coal is considered.

However, the entire operation of one of these chutes requires the labor of one man only, who takes the coal in the car from a side track and places it in a position where the fireman, by pulling a string, does the rest.

In the way of new construction, a branch line has been built from near Sand Coulee to the new coal mines of the Cottonwood Coal Company at Stockett, a distance of 5 miles of main track and 2¼ miles of side tracks. These new mines are located in Cascade county, about 18 miles from Great Falls, and will be in complete operation on a large scale early in the spring, thus greatly increasing the coal output of the State.

I have mentioned only some of the principal works that have engaged me during the past season. Many other improvements of a smaller nature have been made, but you will scarcely be able to take up these even in as brief a manner as I have written. My division is only a small part of the total mileage of the Great Northern Railway in Montana, and on the other divisions there must have been carried on works of interest about which I have not the knowledge necessary to inform you.

ANACONDA WATER WORKS.

Mr. Chester B. Davis, the engineer in charge, referred me to the *Anaconda Standard* of November 6, 1897, for information. In the following description I have quoted liberally from that paper, and have added some points of engineering interest given me by Mr. Davis.

The Anaconda Copper Mining Company has acquired and located rights to all the water in Hearst Gulch. At the extreme south end of it is a crescent-shaped lake named Lake Hearst, about three-quarters of a mile in length by one-quarter of a mile in width, which is fed by the melting of the snows which exist there during the entire year. This lake lies up against Mount Haggin, at an elevation of 8200 feet above sea level, or 2900 feet above the street in front of the Montana Hotel.

The plans contemplate raising the banks of the lake about 20 feet. This will increase its storage capacity to the amount of over 750,000,000 gallons. This, with the other waters in the gulch, which will be tributary to its works, will be equivalent to a daily flow of fully 4,000,000 gallons in addition to the volume of over 13,000,000 gallons at present flowing into the reservoir from the old source of supply.

A pipe line formed of steel pipe about 6 miles long is being built to convey the above waters to an entirely new reservoir in the gulch in which the present one is located. This reservoir, which will be termed the distributing reservoir, will have its water surface, when filled, 320 feet higher than the street in front of the Montana Hotel, and it will be 70 feet higher than the water surface of the present reservoir.

As soon as the new reservoir is completed the old one will be cleaned out and will be kept filled for use in case of emergencies.

The new reservoir will be formed by building an earth and masonry dam across a narrow place in the gulch, and when full the water in it will be 55 feet deep in its deepest place. This will insure its being cold and clear at all times. The pond thus formed will be about 1,300 feet long and about 400 feet in width. Its capacity will be over 70,000,000 gallons, and should an accident happen to the supply pipe leading from Lake Hearst the volume in it would at all times be more than ample to meet the city's needs much longer than the time needed for making the repairs. The shore lines of the distributing reservoir are very irregular, and, lying as it does in the hills, it will be a very beautiful sheet of water.

The dam is a composite structure consisting of a concrete heart-wall founded on a continuous bed of hard-pan at a depth about 18 feet below the natural surface of the bottom of the gulch across which the dam is being erected. This wall is 6 feet in width at the bottom and tapers to a thickness of 20 inches at its top, which is 1 foot above the proposed flow line. The ends of the wall are carried into the bank on each side of the gulch to a good, solid foundation. The dam proper is composed of a very excellent quality of clay which is found close by the west end of the dam. The wet slope of the embankment is $1\frac{1}{2}$ feet horizontal to 1 foot vertical, while the outer slope is $1\frac{1}{4}$ feet horizontal to 1 foot vertical. The top of the embankment is 12 feet wide, and terminates at a height 4 feet above the flow line. The outlet is taken through the solid natural earth at and under the east end of the dam, and no pipes pass through the artificial embankment. The outlet consists of three pipes, one 24 inches in diameter at the bottom, which may serve as a feeder for the city supply, or a means of emptying the reservoir through a 24-inch blow-off outlet into the creek immediately below the reservoir embankment. Vertically above this are two 14-inch pipes, one 15 feet below the water surface and the other 35 feet below it, which serve as the regular outlets for conveying the city supply. These terminate

in a vertical pipe in a dry well in which are located the valves for controlling the flow, and this vertical pipe discharges into the 24-inch above mentioned, which pipe is connected with the 14-inch leading directly to the city. The overflow weir will be located at the easterly end of the dam and will have a length of 50 feet. This will be in the natural solid earth and will be formed of masonry and will discharge into a small ravine which joins the main creek below the dam.

Mr. Davis says: "There are many things of interest in connection with the method of conveying the materials into place in the reservoir embankment, and a number of novel appliances connected with the work, among which I might mention the electrically controlled valves for regulating the flow from the lake down to the reservoir, and which enable us to regulate the flow to any degree of nicety which we may desire by means of an apparatus located in the office of the company in the city. The very great drop, approximating 2600 feet, from the lake down to the reservoir in a distance of 23,000 feet, may also be mentioned as an interesting point. The pipe line is of steel and is self-draining every foot of the way. The work was commenced about the middle of October, and is nearly completed. All of the pipe and special connections were manufactured at McKeesport, Pennsylvania, and have been delivered since the middle of October."

Assurances are given that there will be, within the limits of the system, no place where water will not be thrown to a height of 100 feet into the air, and a test is expected to show that 10 streams each to a height of 100 feet can be thrown directly from the hydrants through one length of hose. The water supply will be ample for a city of 50,000 persons.

As a further means of adding to the beauty of the spot, and of insuring the utmost purity of the supply, the plans contemplate that the supply main from Lake Hearst should terminate in a fountain in the centre of the reservoir. Only a portion of the enormous pressure which might be maintained for this will be used, but it is expected that a solid jet of water two or three inches in diameter will be thrown from its central office fully 200 feet vertically into the air, while around the base of the fountain will be a fringe of spray, consisting of rows of jets rising to varying heights and at various angles. The fountain will be without exception the largest in the world. The jets will rise from a massive base of rough masonry. Across the upper end of the reservoir a settling basin will be built and so arranged as to restrain all drift and dirt which may be brought down during the period when the creek carries flood water.

In the main from each reservoir will be placed a very ingenious device which will accurately measure and automatically record continuously the volume of water passing through the pipe, and at each of these devices and in the office will be a gauge which automatically makes a continuous record of the pressure in the pipes.

IRRIGATION PROJECT.

I am indebted to Mr. Eugene Carroll for the following facts:

In the fall of 1895 the Butte City Water Company diverted the head waters of Fish Creek across the Continental Divide in order to increase its water supply in Butte City. As this necessitated taking considerable water from one valley and turning it into another, so that the water did not return to the stream from which it was taken, it required the purchase by the company of a large number of ranches located along Fish Creek between the mountains and its mouth. In this way the company acquired the title to about three thousand acres of cultivated land. There was left in Fish Creek, after taking out the water from its head, sufficient water to take care of most of the ranches, but in order to make those at the lower end of the creek salable, and to furnish them with an ample supply of water for irrigating purposes, the company, in 1897, decided to construct an irrigating ditch, taking its water from Jefferson River, and extending the ditch past their ranches on lower Fish Creek. In doing this they have permitted ranchmen along the line of the ditch to join with them, and a ditch company is to be formed known as the Creeklyn Irrigation Company.

The company is stocked in such a manner that each share of stock represents twenty-five inches of water. The head-gate of the ditch is placed on the Jefferson River about two thousand yards above the Iron Rod Bridge, and winds on a grade of two and six-tenths feet per mile for thirteen miles, emptying into Fish Creek. The ditch is designed to carry, in solid ground, one thousand inches of water, a liberal allowance being made for evaporation and seepage. The excavated earth from the ditch forms an embankment on the lower side of the ditch, which will be carefully built, and which, in the course of a few years, will more than double the capacity of the ditch. There are no peculiar features about the construction of this ditch. It is necessary to go through the town of Silver Star, and this is done by placing a covered flume along the main street of that town. The total length of the ditch is about 13 miles and about 40,000 feet of lumber are required for bridges and flumes. The contracts are let and the first mile of the ditch is about completed.

The contractors have until the 15th of June in which to complete the work. The head-gate is built of lumber supported by concrete masonry and is twelve feet wide. The bottom of the head-gate is placed at two feet below the bottom of the river at the point of diversion.

WATER POWER.

The development of power from our rivers has been the most important engineering work of the year.

CANYON FERRY DAM.*

At this point on the Missouri River the dam of the Helena Water and Electric Power Co. is nearing completion. The cribbing is now 25 feet above the original surface of the water, and all masonry, excepting the power house walls and transformer house foundation, is completed. The four sets of water wheels of the American Special Turbine pattern, which will give approximately 3500 horse-power, are in place, and also two turbines of 150 horse-power each for running the exciters. Two 12-foot penstocks of steel carry the water from the forebay to the sets of large wheels.

The work, when completed, will contain 2,000,000 feet B. M. of timber and plank. It was commenced July 4, 1896, and will be finished early in 1898.

Mr. Theron M. Ripley, the engineer in charge, to whom I am indebted for the foregoing notes, has promised the Society a paper on this subject, and it will be awaited with great interest.

DAM ON BIG HOLE RIVER.

Mr. M. S. Parker, who has charge of the work, has kindly furnished me with the following notes on this enterprise:

The development of a water power by the Montana Power Company on the Big Hole River, three miles above Divide Station, on the Oregon Short Line Railway, has been in progress since September 1, 1897. The object of this development is to furnish power to be transmitted electrically to Butte, 22 miles distant. The development consists in the construction of a crib dam across the Big Hole River, having a length of 500 feet, with a height of 56 feet from low-water mark to spillway crest. The spillway has a width of 222 feet, the balance of the dam being 10 feet higher than the spillway.

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*See Mr. T. M. Ripley's paper upon the Canyon Ferry Dam, on page 331 of the present number.

The dam has a base width at highest part of 100 feet. The spillway portion of the dam is a series of steps 10 feet high except the top step, which is but 6 feet in height. The tread of the step is 7 feet and the incline is 6 inches to one foot in height. The high portion of the dam is carried up in 10-foot steps with vertical faces.

The dam is to be filled with rock. The upstream face is covered with 7 inches of plank, two layers of 2-inch plank and one of 3-inch, with concrete core extending from bed rock to above the original ground surface. The excavation in front of the dam is replaced with concrete, or slag puddle as circumstances require, the whole to be faced with an earth embankment. Water is to be taken to the wheels through a large flume, the inside dimensions being 15 feet in width and 28 feet high. From this flume water is to be taken to the wheels through steel penstocks 6½ feet in diameter.

The power house is a building 65 x 120 feet ground plan, equipped with four special turbine wheels made by James Leffel. These wheels are 61 inches in diameter and are to furnish 1200 horse-power each under 60-foot head. This head will be maintained by using flash boards on the crest of the dam. The pattern of these wheels is the same as used for the recent Niagara power development.

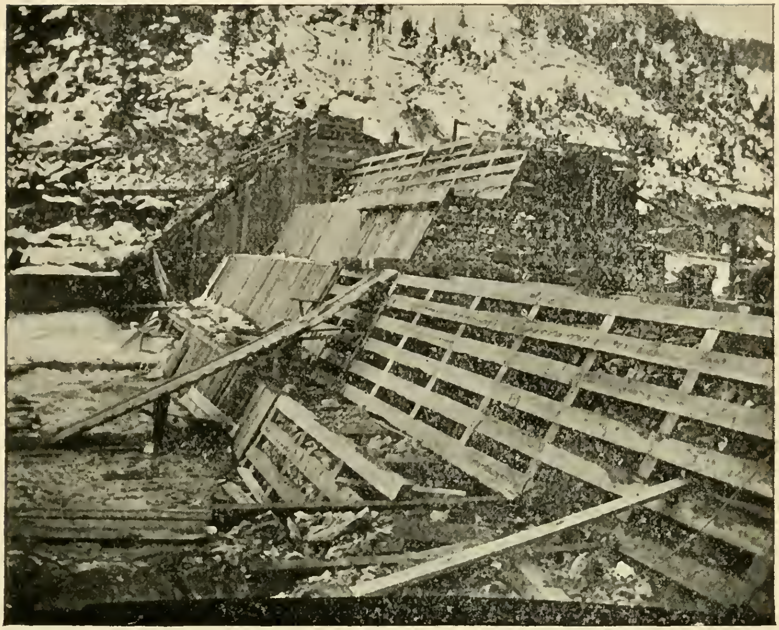
These wheels are direct-connected with electric generators for furnishing the current for transmission. The plan also contemplates the adding of two 1000-horse-power engines connected on the same shaft to two of the wheels, the engines to be used as supplementary to the water power. Beside the four large turbines are two small 150-horse-power wheels to furnish power to the exciter plant. Provision is also made for adding a fifth 61-inch turbine, should it be deemed advisable at a later date.

The power house will be equipped with two 7-ton cranes working jointly for handling the machinery.

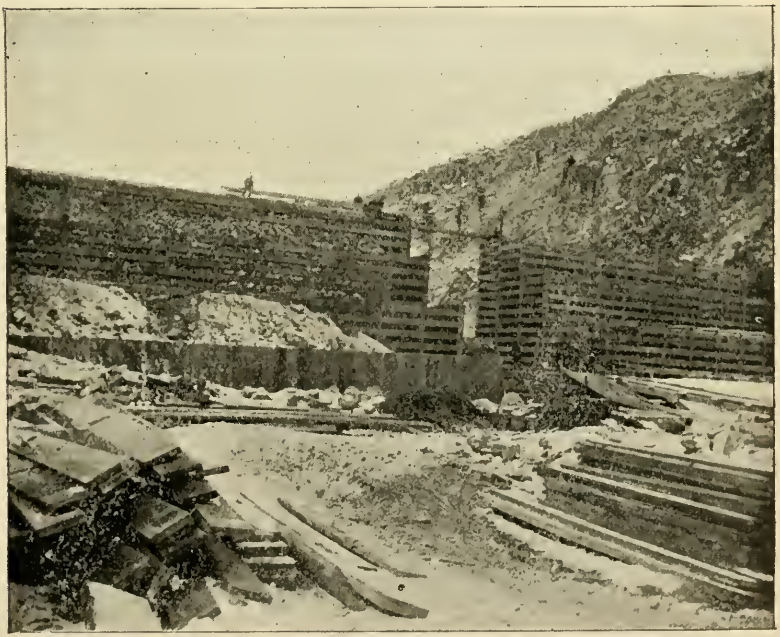
From an engineering standpoint there is nothing novel in this construction. The dam is the highest dam of its class that I am aware of. Concrete is being substituted for rubble and dressed stone masonry in the foundations, thus departing from the usual practice of using stone masonry exclusively.

The power house and transformer building will be fireproof, with iron roof.

Twenty miles above this dam another one is being constructed for storage purposes. It will impound a billion cubic feet of water. I am informed by the contractors, Winters and Parsons, that 60,000 cubic yards of earth will be moved in constructing



Big Hole Dam, Montana Power Company.



Big Hole Dam, Showing Gate Chamber.

this dam. Further particulars regarding this and other features of the enterprise may be expected when Mr. M. S. Parker reads his promised paper to the Society.

TREATMENT OF MILL TAILINGS.

During the past year the Montana Mining Co., Ltd., following some experiments made in the year previous, has undertaken to treat its tailings by the cyanide process, and has constructed a plant with a capacity of 400 tons of tailings per day. Mr. C. W. Merrill, metallurgical engineer in charge of the operations of the plant, has given me the following notes regarding it:

The tailings beneficiated during the preceding summer in the new cyanide plant of the Montana Mining Co., the largest then in operation in this country, were taken from what is known as their No. 5 dam.

This bed, the lowest of the five, situated in Silver Gulch, is about six miles below Marysville, and contains a much greater portion of slimes than the upper beds, owing to the fact that it has been largely used for final settling and clarifying of the water. Therefore the first step in the process of treatment, that of putting the material in suitable shape for leaching, before loading it into cars, is one requiring considerable care. In order that this point may be perfectly clear, it should be explained that in the operation of any lixiviation plant the material handled from day to day should be as nearly uniform in fineness as it is practicable to obtain it, and also that as few slime lumps as possible should be charged into the leaching vats, because they are not only impermeable to the solution, but soak it up and do not release the values so dishonestly obtained.

To accomplish this preparation, the bed is plowed, harrowed and worked over continuously in order to try and partially pulverize the lumps. The further precaution is observed of so selecting the material from different areas on the bed as to give comparatively uniformly leaching charges each day.

The second step, that of loading the cars, is accomplished in the old Mormon fashion, using traps or bridges over railroad cuts and scrapers for moving the material. The pattern of the latter is known as the Fresno Buck scraper, and the economy and advantage of their use will be appreciated by contractors when it is stated that we have been loading approximately 400 cubic yards per day with 6 men and 12 horses, with an average haul of not less than 100 feet. The use of the steam shovel in this work is prohibited by

the fact that the material must be dried and pulverized on the surface of the bed before loading.

The cars used are of three tons capacity, with bottom discharge, and sixteen loaded cars make the train for a 22-ton locomotive.

The plant is $2\frac{1}{2}$ miles above the No. 5 dam, and the tailings, after leaving the cars, pass in an almost continuous stream to the sheet-iron lining of the bin and out the gate to a 24-inch 4-ply belt conveyor, which conducts them to a revolving chute or distributor, and this in turn fills a vat, 38 feet in diameter by 9 feet deep, with 400 tons of tailings in about 8 hours. The great advantage in filling a tank in this way is that it gives a charge of more uniform permeability than any other method of filling known to the writer.

There are four of these tailings vats, each with its bin conveyor and distributor, and one is charged daily, thus giving four days to complete the treatment of each charge, which consists in saturation, lixiviation, washing and discharging. The latter is accomplished by sluicing with two $2\frac{1}{2}$-inch hose, the water being under a 60-foot head, through four side-discharge gates, and one bottom-discharge valve in the center of the vat. By this method 400 tons are discharged in three hours or less, at a total cost of less than 2 cents per ton.

The solution tanks are six in number and consist of four precipitating tanks 22 feet in diameter by 14 feet 9 inches deep and two storage or supply tanks 38 feet in diameter by 9 feet deep. There are also two water tanks 22 feet by 14 feet 9 inches for the storage of 80,000 gallons of water.

The power equipment consists of a 50-horse-power boiler, one 25-horse-power engine, one 10-horse-power engine for running conveyors, one 30-light dynamo, one Knowles economical geared pump, 4-inch inlet and discharge, two Worthington all-iron duplex solution pumps, 5-inch suction and 4-inch discharge, and one 2-drill air compressor.

The tailings are the lowest grade in gold of any being worked in this country; they are the most rebellious of any being worked in the world, because they contain copper carbonates and sulphide, tetrahedrite, arsenical polybasite and ruby silver. The plant operates under the most unfavorable climatic conditions, being in the most Northern latitude of any known to the writer, but in October and November it exceeded the prediction of profit by nearly 50 per cent., and netted about double that which the company thought would justify the erection of a plant.

The railway line for the transportation of the tailings from the

dams to the cyanide plant was surveyed and built under the direction of Mr. John Herron, Mine Superintendent of the Montana Mining Company, and from him I have obtained the following description of the line:

The cyanide plant of the Montana Mining Company is situated in the canyon of Silver Creek, $2\frac{1}{2}$ miles below the town of Marysville. The site, outside of the favorable physical features, was chosen as being half way between the extreme upper and lower tailings dams of the company. There are five of these dams, and it was originally intended to convey the tailings to the plant by railway transportation.

It is probable, however, that the three upper dams will be sluiced to the fourth, and railway transportation be limited to a distance of three-quarters of a mile above the plant and two and one-half miles below it. The capacity of the plant is 400 tons per day.

The railway connecting the plant and the tailings dams is 3 feet gauge, laid with fir ties 5 x 6 inches x 6 feet long, and 56-pound steel rails. The maximum gradient is 3.5 per cent. and the maximum curvature 30°.

The engine used is a Porter six-wheel connected with 12 x 18-inch cylinders, total wheel base nine feet, with a total weight on drivers of 44,000 pounds. Complete terminals are provided.

The water supply comes from Saw Mill Gulch, a mile distant, and is carried by a ditch to a point opposite the plant, and then siphoned to the tanks above the plant.

All tanks and vats are made of California redwood, and all gates, valves and ironwork connected with them were furnished by California firms. All machinery and railway equipment were purchased in the East.

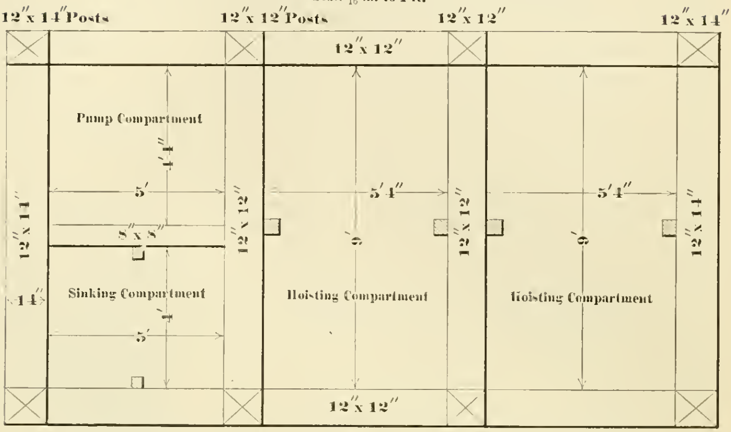
Cost of plant proper was...........	$56,000.00
Cost of railway	14,000.00
Cost of railway equipment.........	12,000.00
Total	$82,000.00

MINING APPLIANCES AND EQUIPMENT.

At Marysville the Drum Lummon Mine will soon have in operation a new Riedler pump with a capacity of 500 gallons per minute and a lift of 1200 feet. A pump of this pattern has been in use in that mine for two years and a half. In recent months it has been run up to its rated capacity, 400 gallons per minute, and has given perfect satisfaction.

Boston and Montana Co's West Colusa Shaft.

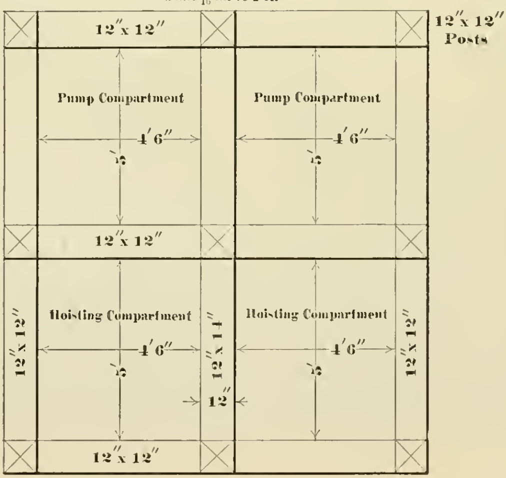
Scale $\frac{1}{16}$ in. to 1 ft.



Sets placed at 5 ft. centers and also at 2½ ft. centers in heavy ground.

Butte and Boston Co's Silver Bow Shaft No. 3

Scale $\frac{3}{16}$ in. to 1 ft.



In Butte the past year has brought about the introduction of several new and noteworthy changes.

The two great hoisting engines of the Anaconda Company, which were mentioned in Mr. Herron's address last year, began operations a few months ago, and a self-dumping skip of 8 tons capacity is used in the Neversweat shaft, where one of these engines is at work. Two large boilers of the Berry Safety type have been installed by the same company, and a fine steel head frame, the first in the State, has taken the place of a timber frame at the St. Lawrence shaft. The hoisting engine at this shaft, with cylinders 30 x 72 inches, is the largest in the State.

At the Silver Bow Mine, on the 1000-foot level of No. 1 shaft, there is a new Nordberg pump, and the four-compartment shaft on the same property is worthy of note. The West Colusa also has four compartments and the cages will carry two mine cars, end to end. The hoisting engine, made by the Nordberg Company, is a new one.

COAL MINING.

The production of coal has increased during the past year, and new mines are being opened up. In Carbon county, near Gebo, the Anaconda Company has started a shaft which will be sunk to a depth of 800 feet, and will develop the coal measures of that district.

And now a few words more in relation to our Society.* Its influence has been felt in the passage of an amendment to the road law by the last Legislature, which placed the care of roads throughout the State in charge of County Surveyors, who certainly should be better qualified than Supervisors appointed by the County Commissioners without special regard for their fitness for such duties.

Three years ago the Society made a strong effort to have a law passed by the Legislature making a cubic foot per second the legal standard for the measurement of flowing water, and providing that 100 miners' inches should be equivalent to a flow of two and one-half cubic feet per second. Although temporarily defeated, we are not discouraged, and in the near future we shall try to convince a legislative body that such a law would not make the settlement of disputes between water right claimants more difficult, but easier; that it does not necessarily follow, because old-

*See Proceedings of Montana Society of Engineers, published in the Journal of the Association of Engineering Societies, Vol. XVIII, No. 3.—1897.

St. Lawrence Head-Frame.

timers have measured water "before we were born," that their method cannot be improved upon; and that the proposed law is not a dark, dubious and diabolical scheme of engineers which will require the introduction of high-priced new appliances for the measurement of water.

In retiring from the presidency of the Society two years ago, Mr. Keerl pointed out that men of engineering skill and experience should be appointed by the Executive to positions where such qualifications would be of decided advantage to the State. It is to be hoped that the suggestion will be kept in mind.

In conclusion I desire to call attention to the fact that more papers on engineering subjects would increase the interest in our meetings. If you feel inclined to set up the excuse of having no time, try a little introspection and see if the real explanation is not lack of resolution. An eminent historian, in reviewing the life of Cæsar, closes with these words, "So true it is, that it is not time which is wanting to men, but resolution to turn it to the best advantage."

THE CANYON FERRY DAM.

By Theron M. Ripley, Member Montana Society of Engineers.

[Read before the Society, January 8, 1898.*]

The practicability of damming the Missouri River near Helena, Montana, for power purposes, has been considered more or less favorably by engineers and business men of that city for a number of years. In fact, one party made preliminary surveys at a point on the river about six miles below the site of the present work, but never got beyond the preliminary stage. Moreover, the government made an examination of the Missouri River from Three Forks to Canyon Ferry in 1893, under the direction of Capt. H. F. Hodges, and surveys and maps were made by E. L. Vincent, assistant engineer, of five dam sites between the two places mentioned, the fifth one being at Black Rock Canyon, at the site of the present works, eighteen miles northeast from the city of Helena. The maps above mentioned have been of great value in prosecuting the present work.

Government investigations at the site of the present works place the mean flow of the river at 3300 cubic feet per second; that amount, with a twenty-nine-foot fall, is equal to about 358,875,000 foot pounds; which, with wheels of 80 per cent. efficiency, would give 8680 horse-power on wheel shaft.

The project of the present work was promoted by one H. L. Cooper, under the direction of Samuel T. Hauser and Thos. A. Marlow, through whose influence, together with that of Barton Sewell, of Chicago, the funds were obtained for prosecuting the work, and the company incorporated under the name of the Helena Water and Electric Power Company, with Mr. Sewell as general manager.

J. T. Fanning, of Minneapolis, was retained as consulting engineer, and all plans for the dam, power-house and hydraulic machinery have been made in his office. Moreover, the work has had his personal supervision from time to time during its progress. The dam is a timber crib, filled with rock, with three aprons to break the fall of water and thereby reduce the scour below the dam. The timber in the cribs is fastened together with 20-inch and 30-inch drift bolts, and the end cribs rest against pilasters in the abutments, which rise to a height of 12½ feet above the crest of the dam. The abutments being built on the edge of the original shore line,

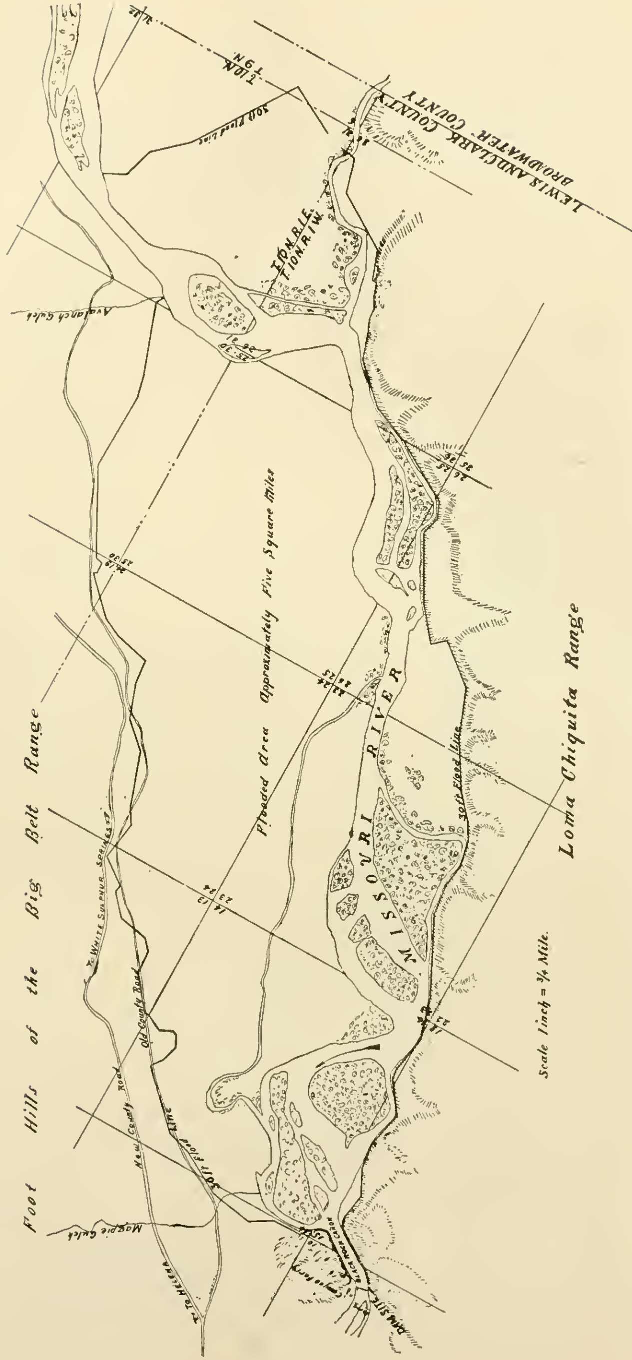
*Manuscript received March 24, 1898.—Secretary, Ass'n of Eng. Socs.

the length of the spillway or crest is practically the same as the width of the river at the site. The aprons are built of two courses of 10 x 12-inch timbers, laid on the 12-inch side, thus giving a total thickness of 20 inches of solid timber under each fall. The risers are covered with two thicknesses of 3-inch plank, lap-jointed, and the back with 2-inch plank, similarly laid. Above the dam, and resting against it, is an earth fill, which is rip-rapped below any possible wave action or floating drift. Below the dam, for a distance of 25 feet, the river was filled with large rock to the surface of the water, the rock being held in place by a close row of round piles. The distance from plank facing on back of dam to said row of round piles is approximately 75 feet; the crest is 29 feet above mean low water, and its length is 485 feet. The cribbing rests on the bed of the river, which is compact material composed of gravel and granite sand, and practically impervious to water. Cofferdams, with the sheet piling, forming same, being driven to depths of only 4 and 5 feet, had their enclosed spaces exceptionally free from water when working under a head of 10 feet, with the material excavated as close to the piling as its natural slope would allow, without undermining the sheet piles. Both above and below the cribbing was driven a row of triple lap-sheet piling built of 3 x 12-inch plank, stiffly bolted together, driven to a depth of 12 feet below the bed of the river, or, when the material was too hard, until the pile was in danger of splitting, or would go no further under the blows of a 2250-pound hammer falling on a 1100-pound cast follower, placed on the head of the pile. All masonry, where possible, had a similar row of sheet piling driven around its foundation, as an extra precaution against a current forming under the structure.

On the east bank of the river, a fill, with a slope of $1\frac{1}{2}$ by 1 on the downstream, and 2 to 1 on the upstream side, was built with a masonry core, to the height of the abutment, and extended back to the corresponding contour on the hillside. This fill is practically an extension of the dam proper, but not designed as a weir.

Adding to the length of said fill (285 feet), the crest length (485 feet) gives a total length from west abutment to east end of 770 feet. The west abutment rests on the native rock, and the cliff rose from this point at an angle of 45 degrees. Out of this cliff, about 18,000 cubic yards of rock were taken to make the forebay and the excavation for the penstocks. From the back of the abutment, and extending across the excavation just mentioned, is a heavy masonry wall, which holds the penstock heads.

The penstocks, five in number, extend from this wall to the power-house, 75 feet north. The penstocks were built on the



MAP OF COUNTRY FLOODED BY ERECTING A 29-FOOT DAM AT CANYON FERRY.

ground, of 5-16-inch steel plates, furnished under contract, by the Gillette-Herzog Manufacturing Company, of Minneapolis. Of the five penstocks, four are 12 feet in diameter, each designed to furnish water for two pairs of 42-inch horizontal turbines, and the remaining one, which is 4 feet 6 inches in diameter, will supply a single 25-inch horizontal wheel. Each set of turbines will be directly connected by an 8-inch shaft, to a 650 k. w. alternating current generator, two phase, 7200 alts., 550 volts, 157 r. p. m. Each 25-inch turbine will be similarly connected to a 100 k. w. direct-connected, excitor, each machine being capable of taking care of the entire plant. The turbines were furnished by the Dayton-Globe Iron Works Company, of Dayton, Ohio.

The portion of the power-house now under erection, in conformity with other masonry on the work, is being built of granite, quarried near the site of the work, and the dimensions will be 50 x $87\frac{1}{2}$ feet.

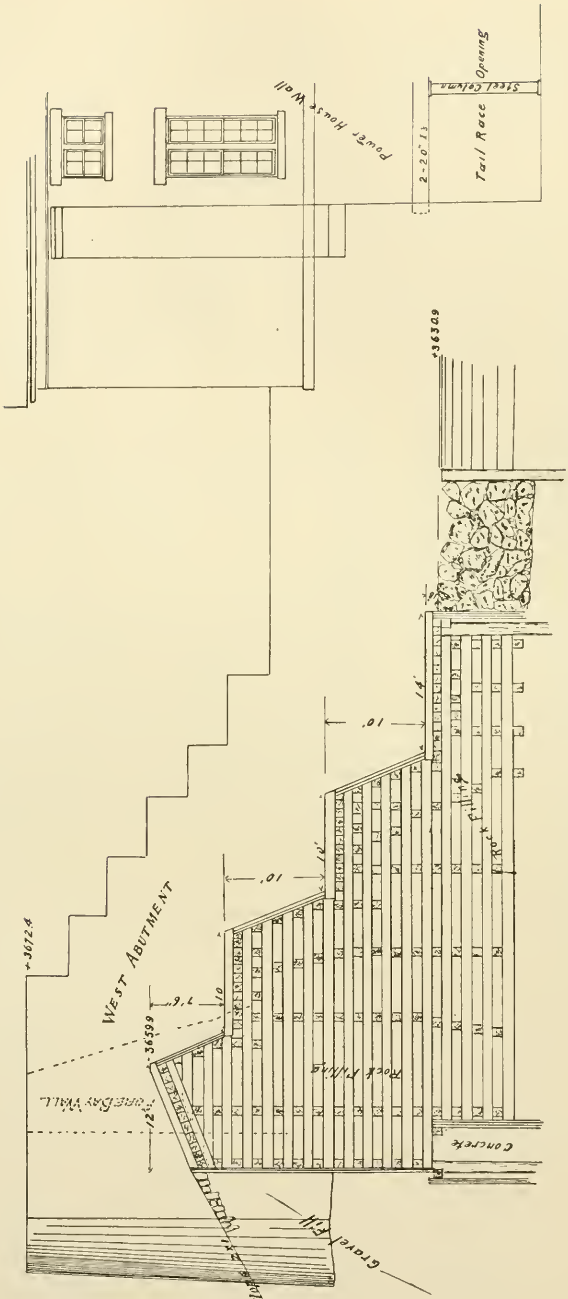
The transformer-house at the dam is 65 x 30 feet, built of iron, and large enough to accommodate the plant when enlarged to its full capacity. Eight 325 k. w. transformers will be installed for the four machines being put in at present.

The granite quarry before mentioned was opened on the company's ground about 800 feet from the site of the work, and has furnished rock for about 7000 cubic yards of masonry, said rock being delivered on the work by a gravity railroad. The timber, 2,000,000 feet B. M., was furnished under contract by the Big Blackfoot Milling Company. The timber was shipped by rail to Townsend, thirty miles up the river from the work, and floated down the river at much less cost than it could be freighted overland from the nearest railroad station.

The rock filling, in and below the dam, amounts to 14,000 cubic yards, and the earth fills aggregate 23,000 cubic yards.

The fall of the river, above the dam, averages about 5 feet per mile, consequently the flood line extends up the valley a distance of six miles. The lake formed above the dam has an approximate area of five square miles, with an extreme depth of 60 feet in the canyon about 800 feet above the dam, making the finest body of water within a radius of 150 miles from the city of Helena.

The pole line is built at the present time, via East Helena, to the city limits of Helena, and the first power delivered will be to the United Smelting and Refining Company's plant at East Helena. The poles are Idaho cedar, placed 110 feet apart, with a minimum length of 35 feet. Each pole has two 10-foot-6-inch arms, six pins per arm, for transmission purposes, and one small



Cross-section of Dam and Elevation of West Abutment and Power-House.

arm for telephone. Three No. 4 copper wires, Brown & Sharp's hard-drawn, will be used for transmission from each machine.

I am indebted to Mr. C. W. Whitley, assistant secretary and treasurer of the company, for information relating to electrical machinery and transmission.

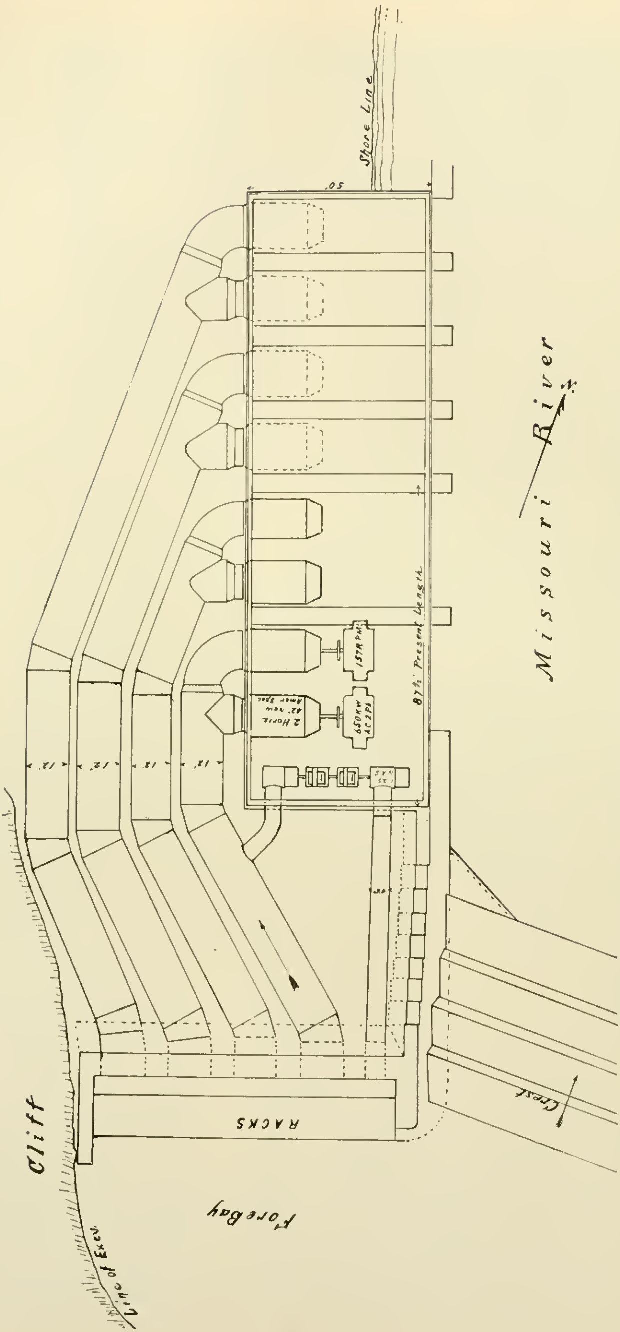
DISCUSSION.

In reply to questions, Mr. Ripley stated: At first Rosendale cement was used, but it was unsatisfactory. During the past nine or ten months two thousand barrels of Utah Portland cement have been used, to the entire exclusion of inferior brands. The work constructed with Portland cement is much more satisfactory. The small additional cost was too trifling to consider in making the selection.

The wheels used at Niagara are vertical, while here a horizontal wheel is used. I was informed by a representative of an American wheel company that when the Niagara plant was put in the American companies were afraid to undertake the work, so it was done by foreign companies.

Mr. Wilson.—I would like to ask Mr. Ripley and Mr. Parker how they propose to deal with the floating and submerged ice, to keep the same out of the wheels. In speaking to the general manager of Mr. Ripley's company, he stated there would be a large reservoir which would afford the proper remedy.

Mr. Parker.—I have had considerable experience with anchor ice during the past six or seven years. I have observed its operations very carefully, and have had much to do in endeavoring to eliminate its operations upon the wheel. A large reservoir will greatly help in the matter, especially if it be deep. At Great Falls, the Black Eagle Falls dam reservoir is only 17 feet deep at the face of the dam, and has a capacity of from 20,000,000 to 25,000,000 cubic feet. Our principal trouble was with the small wheels, the large wheels being less interfered with. Occasionally the small wheels would be absolutely stopped. The anchor ice appeared to pass through the large wheels, but would catch and stick to the small wheels. The anchor ice gathers in the bottom or is held in suspension, and has a tendency to adhere to everything with which it comes in contact. Several times during the past four years it has been piled up in the canal eight or ten feet high, and this necessitated the closing down of the works to clear away the ice in the channel to the wheels. This would not occur in a large and deep reservoir. I consider that the only remedy is to have large storing capacity and to give the ice in the river time to get back to its



Plan of Power-House, Penstocks and Head-Gate Masonry.

normal condition. With a small reservoir an ice gorge would affect the operations of the power.

President Page.—To relieve the anxiety of the minds of many people living in the vicinity of the Big Hole dam, I would like to ask your opinion as to the durability and stability of the dam now being constructed on the Big Hole River.

Mr. Parker.—The dam is built with all the necessary precautions as to strength and durability to resist all the pressure that may be brought to bear upon it. Mr. Fanning, the consulting engineer, has a world-wide reputation as an hydraulic engineer, and would not be associated with a project that would subject the people to loss of life or property; neither would the company spend half a million of dollars in an unsafe structure. Everything has been and is being done to insure perfect construction. Mr. Fanning is also consulting engineer of the Missouri River dam, of a similar pattern and design; and both dams are being built in a perfectly safe manner.

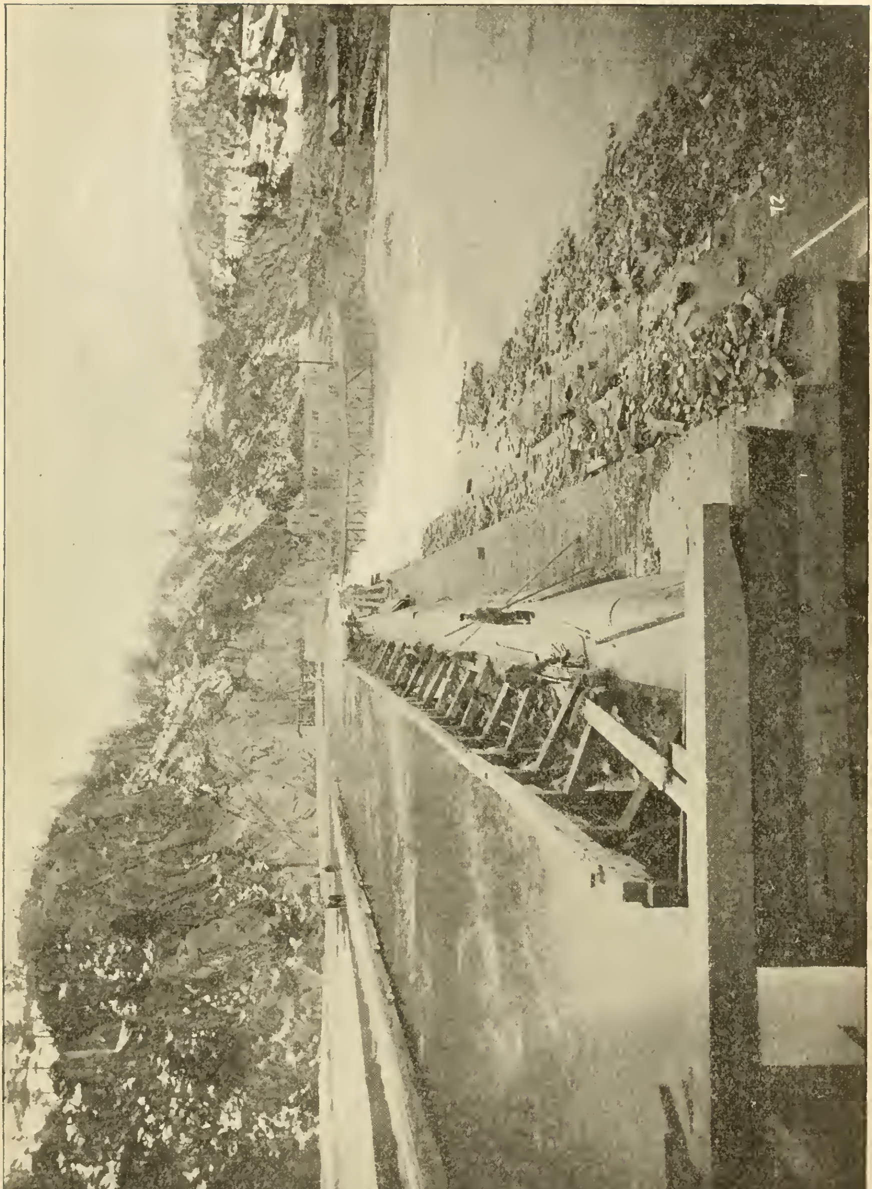
President Page.—In case of a washout, will not the cribs stand, or at least refuse to go out in a mass?

Mr. Parker.—A dam of this type will not give way and go out in a body, as an earthen or masonry dam would do. A crib dam is put together in such a way that were there no filling in it whatever the structure would stand and carry its own weight, and probably the weight of the water added to it. The total pressure is over two and one-half times as great as the pressure of the water. The width of base and the strength of the structure throughout give it practically a factor of safety of about six to one.

Mr. Herron.—At what do you estimate the life of the timber? Will there be enough seepage to keep the timber wet, and does the plan of construction take into account durability as well as strength?

Mr. Parker.—The life of timber is somewhat indefinite. In Connecticut old timbers were taken out and replaced by new in a structure that had stood for over one hundred years. They had remained sound. We all know that timber only partially exposed to water will deteriorate in time, but below the water line it will not deteriorate. I have made various inquiries throughout the United States with regard to this matter, and I have never found an instance where the timber had been worn out or become decayed. The exposed surfaces of dams have to be repaired as occasion demands. Mr. Fanning estimates the life of the upper portion of a timber dam to be fifty years.

The discussion of dams resulted in bringing about the con-



sideration of the appointment of a State Engineer, who should inspect and look after the numerous storage reservoirs that will doubtless be built in this State in the near future.

PROPERTIES OF CONCRETE UNDER COMPRESSIVE STRESS.

By David Molitor, Mem. Am. Soc. C. E.

[Read before the Detroit Engineering Society, March 25, 1898.*]

Concrete and masonry are generally subjected to compressive stress only. The ultimate tensile strength of these materials often attains high values, yet the lack of uniformity in concrete and masonry, necessarily brought about by the customary methods of construction, introduces an element of uncertainty which wholly unfits them for purposes requiring tensile resistance. This factor of uncertainty in concrete, to resist tensile stresses, has been successfully overcome by various styles of iron and concrete construction now in use. In all of these, however, the concrete is used in compression and the iron in tension.

Concrete, therefore, being most universally used under compressive stress, it would be natural to suppose that modern literature abounded in data and experiments on the properties of concrete under compression. This, however, is not the case. In fact, there is a lamentable want of accurate experiments on the subject of elasticity and compressibility of concrete and mortar.

What is given in the following represents practically the best available data, though the number of experiments is rather limited, and there is a broad field for more good work in the direction indicated.

It is common to see wide discrepancies in the results of tests on compressive strength and elasticity of cement mortars, and many experimenters have given up this line of research in despair of ever being able to obtain harmonious results. The consequence is that tensile tests have been resorted to as giving more uniform results, but even these have differed so widely as to create grave doubts regarding the possibility of obtaining concordant values even from one and the same sample of cement.

However, in the case of tensile tests these discrepancies are most probably due to a lack of uniformity in the preparation of test specimens, and in the case of compressive tests the shape of the specimen is of such importance that it is scarcely possible to compare values of compressive strength obtained from samples of different dimensions.

*Manuscript received May 16, 1898.—Secretary, Ass'n of Eng. Socs.

Some recent experiments made by Prof. Bauschinger, in Berlin, Germany, show that the compressive strength of sandstone varies from 680 atmospheres to 2140 atmospheres, depending upon the relation between base and height of the test specimen, the height being in no case greater than the square root of the area of the base. When the height of the specimen became three times the square root of the base, the compressive strength diminished from 582 to 444 atmospheres. It was also demonstrated that cubes gave a practically constant value for the compressive strength no matter what size, between the limits of 2 and 4 inches. The same laws were found for concrete, but the experiments are not of sufficient extent to permit the deduction of the law of variation between its compressive strength and the dimensions of the samples.

Prof. Bauschinger derives the following equation as representing this relation:

$$P = \left(\alpha + \beta \frac{\sqrt{A}}{h} \right) \sqrt{\frac{\sqrt{A}}{\frac{c}{4}}} \qquad (1.)$$

in which P = the ultimate compressive strength.

A = area of the prism.

h = height of prism.

c = periphery of prism.

α and β are constants, depending on the nature of the material.

For prisms of square cross-section this equation becomes

$$P = \alpha + \beta \frac{a}{h} \qquad (2.)$$

in which a is the side of the square base.

According to Prof. Bauschinger, samples of a grayish blue Swiss sandstone gave the following results:

Sample.	Dimensions.	Area.	Ult. Compressive Strength.
	Inches.	Sq. in.	lbs. per square in.
1	3.92 x 3.88 x 3.78 high	15.35	9,670
2	3.94 x 3.88 x 3.82 "	15.42	9,741
3	2.36 x 2.30 x 2.24 "	5.44	9,527
4	2.05 x 2.05 x 1.99 "	4.19	9,812
5	1.89 x 1.85 x 0.43 "	3.49	27,729
6	1.97 x 1.81 x 0.43 "	3.56	27,160
7	1.73 x 3.82 x 0.43 "	6.62	30,431

The constants α and β were determined for the above values, and when substituted in equation (1) give:

$$P = \left(4408 + 4920 \frac{\sqrt{A}}{h}\right) \sqrt{\frac{\sqrt{A}}{\frac{c}{4}}} \qquad (3.)$$

From this equation it follows that the ultimate compressive strength of a cube of this same material would be 9328 pounds per square inch. The pressure in the above series was applied perpendicularly to the natural bed. The above equation (3) is claimed by Prof. Bauschinger to hold good only for samples in which $h \leqq 5 \sqrt{A}$. Of course the compressive strength continues to diminish as h increases, and at the limit just stated $P = 5392$ pounds per square inch.

The following tests were made by Prof. Bauschinger in connection with the construction of a concrete bridge over the Danube River, near Munderkingen, Würtemberg, Germany, in 1893. The cement was a German Portland, made at Blaubeuren, Würtemberg, and the samples were 30 days old, being allowed to set 28 days under water. Each value is the mean result from three samples.

No.	Proportions.	Ult. Compressive Strength. Size of Samples in Inches. 4.72 x 4.72 x 5.51 high.	4.72 x 4.72 x 11.81 high.	α	β	Str. of Cube. $= \alpha + \beta$
		lbs. per sq. in.	lbs. per sq. in.			lbs. per sq. in.
1	1 c: 2 s: 4 crushed basalt rock	3143	2247	1678	1962	3640
2	1 c: 3 {basalt screenings: 6 limestone	2019	1251	583	1678	2261
3	1 c: 2 s: 4 gravel.	2161	1578	1066	1280	2346
4	1 c: 2½ s: 5 "	1877	1237	682	1393	2075
5	1 c: 3 s: 6 "	1692	1209	796	1052	1848
6*	1 c: 3 s: 6 "	1379	938	554	967	1521

The values of the constants α and β in equation (2) have been computed and are given in the above table. Equation (2) applies to these tests because the samples were of square cross-section. Even when the cross-section is only an approximate square, this equation would answer in preference to the more complicated form of equation (1).

The above figures only illustrate the effect of the shape of a sample on the compressive strength of the material, but a more extensive series for a greater number of different sized samples and such mixtures of concrete as are commonly employed on works, would be of interest and practical value.

*Quick setting cement.

Another subject of importance to the designing engineer, which has hitherto received little attention, is the behavior of stone or concrete under a single concentrated load. Such cases as a wheel load on a concrete floor or a heavy road-roller on pavement, etc.

A few experiments of this character were made by Durand-Claye in 1885-6 and by Prof. C. Bach in 1888.

The experiments by Durand-Claye were made on 3.94-inch cement cubes, applying the pressure over the limited surface of a steel plate varying from 0.39 inch square to 3.15 inches square and placed exactly in the center of the upper face of the cube. (See Fig. 3, plate 1.) The ultimate compressive strength of this cement was 8191 pounds per square inch on a cube sample. The following table gives the results obtained:

No. of Test	Size of steel plate. z	Breaking Load Distributed over the area. a^2	z^2
	inches.	lbs. per sq. inch.	lbs. per sq. inch.
1	0.39	640	63,535
2	0.79	1,493	37,441
3	1.18	1,991	22,183
4	1.57	3,086	19,296
5	1.97	3,726	14,888
6	2.36	4,721	13,082
7	2.76	5,404	11,020
8	3.15	6,115	9,570

The above figures show that concrete is capable of sustaining concentrated loads to the extent of at least eight times the compressive strength of a cube when the load is appiied to an area equal to one-hundredth the area of the concrete surface. For example, a wagon wheel carrying 5000 pounds and having an area of contact with a concrete surface qual to one square inch would not be straining that concrete to $\frac{5000}{8191}$ part of its breaking strength (assuming this to be 8191 pounds per square inch as above), but to only $\frac{5000}{63535} = \frac{1}{12}$ (about) of the actual breaking load of 63,535 pounds per square inch under these particular conditions. The same wheel in rolling over a 1-inch cube of concrete would probably crush the latter to powder. This data is also useful in designing column foundations, etc.

The experiments of Prof. Bach were made on 3.94-inch cubes (not all exactly alike) of sandstone, but differing from those made by Durand-Claye inasmuch as the steel plate was kept of same length as the sandstone sample, allowing only the width *z* to vary.

(See Fig. 4, plate I.) The results are given in the following table, each value representing the mean of from 3 to 5 samples.

No. of Test.	Dimensions of Samples. inches.			Width of steel plate. inches.	Breaking Load Distributed over the area.	
	a	b	h	z	ab	bz
					lbs. per sq. in.	lbs. per sq. in.
1	3.92	3.95	3.87	0.20	1,450	29,151
2	3.93	3.92	3.87	0.39	1,706	16,964
3	3.95	3.95	3.86	0.59	2,216	14,854
4	3.94	3.94	3.88	0.79	2,677	13,409
5	3.95	3.93	3.89	0.98	3,299	13,168
6	2.54	2.37	2.36	2.37	9,286	9,286

In both of the above sets of experiments it was found that the failure of the samples was caused by the formation of a wedge under the steel plate which forced the cubes apart by wedge action.

The subject of most importance in connection with engineering work is the elasticity of cement mortar and concrete under compressive stress. The limited number of experiments in this direction has given rise to a diversity of results directly proportional to the number of experiments. This wonderful lack of uniformity in results remained a mystery until Prof. C. Bach, of Stuttgart, Germany, in 1895, showed by a series of experiments on concrete prisms that it was not the uncertainty in the material, but the method of measuring the deformations that was responsible for the wide discrepancies in values obtained for the modulus of elasticity of concrete.

The fact that every brand of cement and every mixture with sand or stone, or both, constitutes a different kind of material, seems to have been entirely overlooked, while in reality a mortar mixed 1 part cement to 5 parts sand differs from a concrete mixed 1 part cement to 2 parts sand to 4 parts broken stone as widely as does sandstone from granite, and no one would expect to obtain the same value for the modulus of elasticity in the two last-named stones. Prof. Bach has, however, simplified this relationship between composition of concrete and its elastic properties by dealing solely with the breaking strength as a function of the composition and age of the concrete, thus eliminating an infinite series of special values and obtaining values of general utility and application.

The following is a description of the methods and apparatus used in making these experiments and the results obtained therefrom.

The samples were 39.37 inches long and of circular cross-section 9.84 inches in diameter mixed in the following proportions:

1 part	Portland	cement to	$2\frac{1}{2}$ parts	sand	to	5 river gravel.
1 "	"	"	$2\frac{1}{2}$ "	"	"	5 broken limestone.
1 "	"	"	$7\frac{1}{2}$ "	gravel and sand (dredged).		
1 "	"	"	3 "	sand	to	6 parts river gravel.
1 "	"	"	3 "	"	"	6 broken limestone.
1 "	"	"	9 "	gravel and sand as dredged.		

Three samples were made in each of the above proportions, using Blaubeuren Portland cement for one series and Lauffen Portland cement for a second series.

The Blaubeuren cement gave the following results in tension: On a screen having 5800 meshes per square inch (wire half thickness of mesh) 1.9% were retained. Mixed 1 : 3 standard sand (parts by weight) and 10% water, allowed to set 1 day in air and 28 days under water, gave a tensile strength of 363 pounds per square inch.

The Lauffen cement gave the following results: On above screen 3.3% were retained. A sample of same mixture as above gave a tensile strength of 301 pounds per square inch.

The cylindrical samples were made in wooden molds rammed in with iron rams until water appeared on the surface. They were taken out of the molds after 24 hours and placed in bags, which were kept watered for 28 days. The samples were from 76 to 97 days old when tested. The specific gravity averaged 2.4. The deformations were measured over a length of 29.52 inches.

The method of measuring the deformations and manner of holding the samples in the testing machine are shown on plate 1, Figs. 1 and 2.

The pressure is equally distributed over the ends of the concrete prisms by applying the stress through plates provided with spherical bearings. (See Fig. 1.) The apparatus for recording the permanent set and the elastic deformations is shown in Fig. 2.

Two such recording instruments are fastened 180 degrees apart, and are held in position on the concrete prism by means of rings, as shown in plan of Fig. 1 and Fig. 2. When the prism is compressed under load the points A and B approach each other by an amount $\triangle l$ which is indicated 600 fold on the graduated arc. Fig. 2 illustrates the principle of the indicator, which is not new, except that the arm D E F transmits its rotation to a small spool at G through a flexible metal ribbon instead of gearing, thus avoiding any lost motion in the mechanism. The metal ribbon is tightened by a small weight at the short end of the pointer.

When a sample was placed in the testing machine a stress of 114 pounds per square inch was applied in 1.5 minutes, the deflection read and the stress released to zero. The permanent set was

Fig. 1.

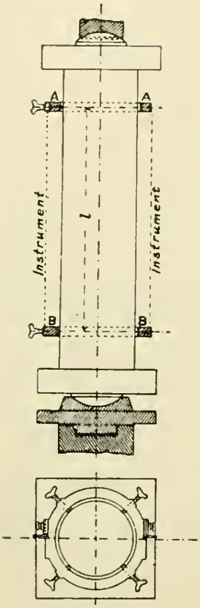


Fig. 2.

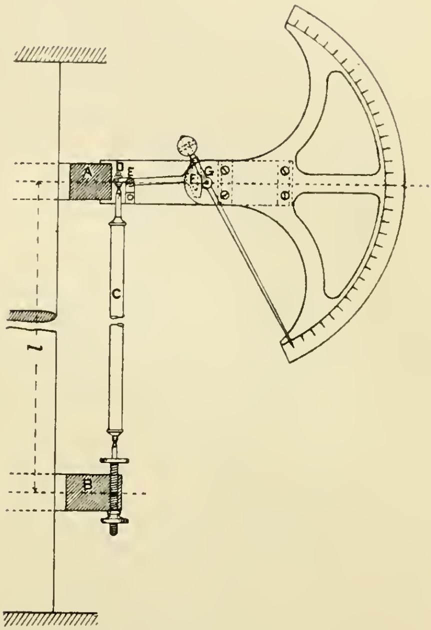


Fig. 3.

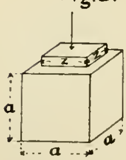
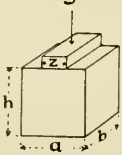


Fig. 4.



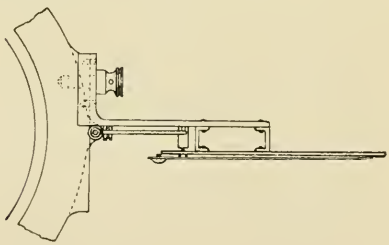


Plate I.

Apparatus for Measuring Deformations of Compressive Specimens.

then observed. This process was repeated until both the elastic and permanent deformations no longer increased. The next set of observations was made by raising the stress to 228 pounds per square inch in 1.5 minutes, allowing the same time in which to release the stress, and this process repeated until the deformations remained constant. Observations were taken in this manner for the following loads: 114, 228, 341, 455 and 569 pounds per square inch, which required from three to seven repetitions of the load before obtaining constant deformations. The limit of 569 pounds per square inch was set as being the limit which would be adopted on the work for which the experiments were made. After these experiments the samples were compressed to destruction.

However, a few samples were tested for deflection for stresses from zero to the breaking load, and such a sample is recorded, with the results obtained, on plate 2. The diagram is self-explanatory, except that a certain point marked *a* on the curve of permanent deformation indicates the stress which, even after seven repetitions of the load, caused the deformations to increase. Therefore, this appears to be the point beyond which the material cannot be stressed with safety. The moduli of elasticity as found for the elastic deformations resulting from the various loads applied are plotted in the curve designated *modulus of elasticity*. This curve shows that the modulus varies almost inversely as the applied load. The compressive strength—2093 pounds per square inch—found for this sample was determined on the full-sized sample, whose length was four times the diameter. According to the experiments cited in the fore part of this paper, the strength of a cube of same material would have been about one-half greater, or about 3000 pounds per square inch.

The summarized results of all the tests between the load limits of 114 and 569 pounds per square inch are represented graphically on plate 3. The lines representing the relation between *ultimate strength*, *modulus of elasticity* and *applied load* being almost straight, show that the modulus varies inversely as the applied load for a constant ultimate strength. This inverse function, however, depends on the age and composition of the concrete, which two factors are combined in the ultimate strength. Hence, for a certain ultimate strength the modulus of elasticity for any case of loading can be read off the diagram.

In like manner the relation between the *permanent set*, *ultimate strength* and *applied load* is graphically represented by the set of curves on the right half of plate 3. In this case the relation

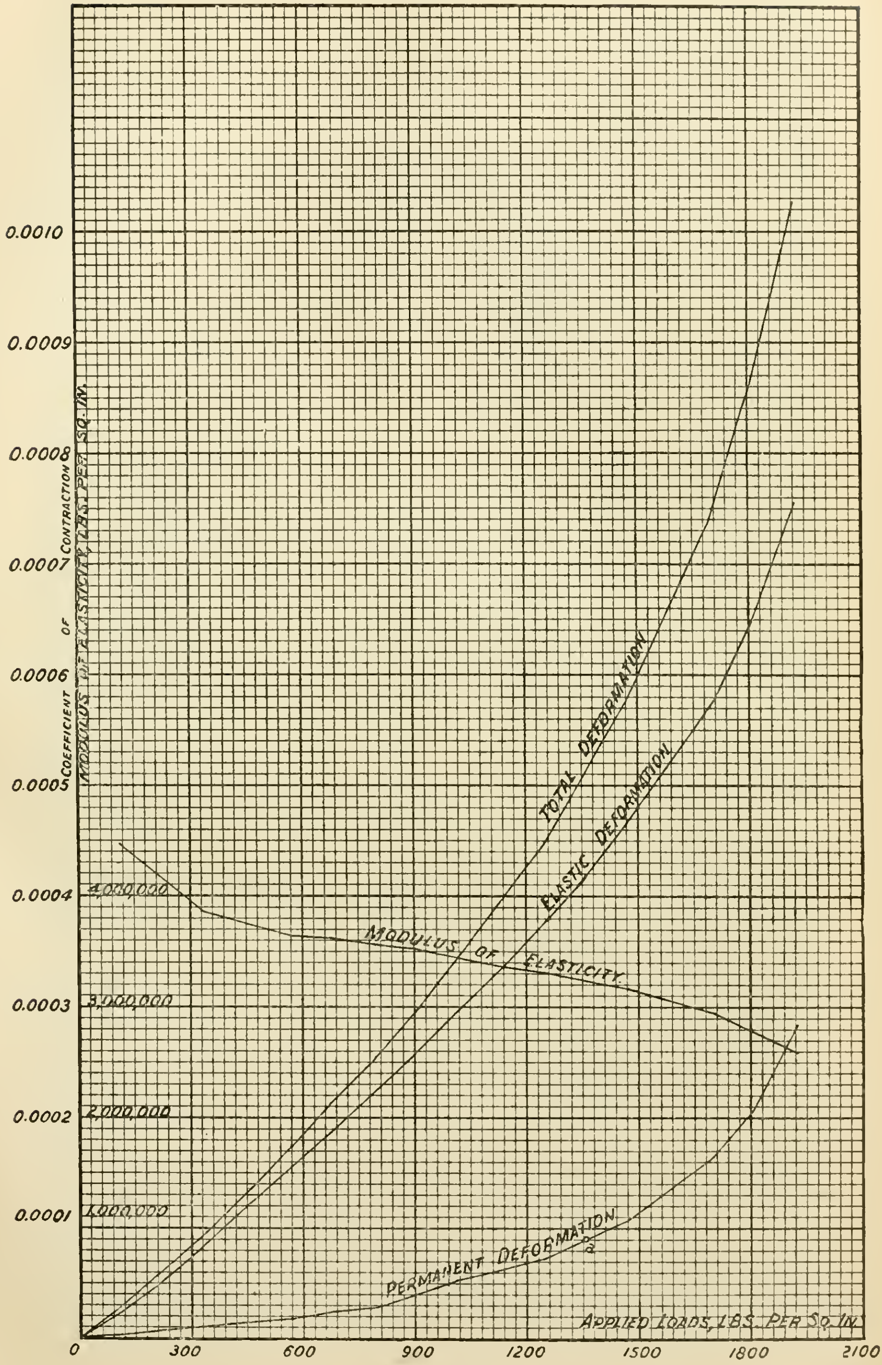


PLATE II.

Sample, 9.84 in. diameter, 39.37 in. high. Deformations measured on a length of 29.52 in. Mixture, 1 part Portland cement to 7½ parts sand and gravel. Specific gravity = 2.40. Age, 93 days, ult. comp. strength 2093 lbs. per square inch.

between *modulus of permanent set** E^1, and the *applied load* for the same concrete is inverse, but of a higher degree than the first.

It must be remembered, however, that the ultimate breaking loads on these diagrams were obtained from samples of cylindrical shape, having a length of four diameters. The actual breaking strength of cubes of the same concrete would have given results nearly one and one-half times as large. The breaking strength of cubes should have been determined for the above series of experiments, though the results are none the less valuable on that account, as the ultimate strength of the concrete for which the above data is to be used can be determined for similar cylindrical samples.

A limited number of tests were made by Prof. Bauschinger to determine the effect of size of cube on the ultimate strength of cement mortar. The result showed that the larger samples possessed a slightly higher crushing strength than did the small samples, but the difference was not great, and the conclusion to be drawn is that samples of moderate size give results on the safe side. This result is contrary to the behavior of metal in tension, and seems somewhat surprising at first, but a second thought will explain the probable reason for the observed fact. On small samples the slight irregularities in the bearing surfaces and the slight differences in mixture and setting qualities of the cement count for more than on large samples, and as these differences are most certain to exist to some degree, the large samples give a higher ultimate strength.

The following data, not usually contained in text-books, might be given in this connection.

All cement mortars, when setting in air, undergo a shrinkage, and when setting under water, they show little change in volume, though there is a tendency to a slight expansion.

For Portland cement mortar setting in air, the linear coefficient of shrinkage is given by Prof. Bauschinger as follows:

Mixture 1 C. : 3 sand, age 16 weeks....0.0009 to 0.0015.
" 1 C. : 5 sand, " " " ....0.0008 to 0.0014.

The linear coefficient of expansion for 1° Centigrade is as follows:

Portland cement mortar (Bruniceau), 0.00001 to 0.000014.

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*The term modulus of permanent set as here used has the same significance as modulus of elasticity, only that the deformations in the former case are permanent, and in the latter they are elastic. The reciprocal of this modulus would be the coefficient of contraction. The total deformation of a compressed member of area A, length l and carrying load P, would be $\frac{Pl}{A}\left(\frac{1}{E} + \frac{1}{E^1}\right)$.

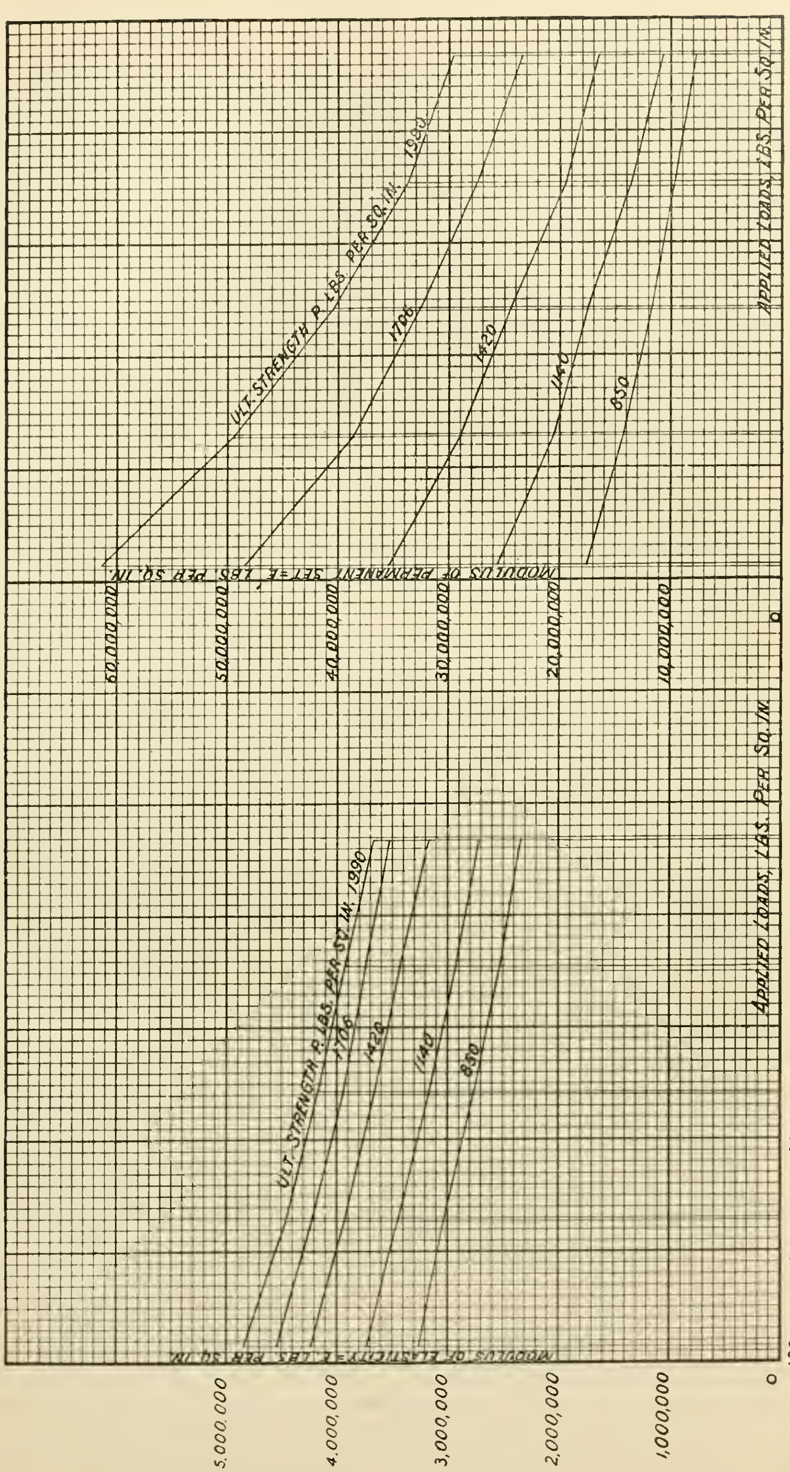


PLATE III.
Relation between ultimate strength. Modulus of elasticity and applied loads.

Portland cement concrete 1:2½:5 (Bauschinger), 0.0000088.

Natural stone and brick (Bruniceau), 0.0000053 to 0.0000083.

Tourstay, in 1885, found that the ultimate compressive strength obtained from laboratory tests on small cubes of cement mortar is considerably less than the compressive stress attainable from blocks of masonry in which the same mortar was used; also, that the strength of the masonry is an inverse function of the thickness of mortar joint. He also found that stone plates cemented together with neat cement grout give an ultimate compressive strength equal to that of the solid stone, while similar stone plates, carefully ground but resting upon each other without cement in joints, break under much less load.

THE STEEL FRAME OF THE ST. LOUIS COLISEUM.

By E. W. Stern, M. Am. Soc. C. E.

[Read before the Engineers' Club of St. Louis, March 16, 1898.*]

In the spring of 1897 it was decided by the St. Louis Exposition and Music Hall Association to alter part of its large building, covering the block between Olive, Locust, Thirteenth and Fourteenth streets, in the city of St. Louis, so as to have a large convention hall or coliseum.

Contracts accordingly were let to alter the northern part of the building, occupying a space of 318 feet x 189 feet, and the work was executed during the summer and fall of 1897.

In the following paper the writer will confine his remarks to the ironwork only of this structure, as that was the part of the work that came directly under his charge, as engineer for the contractor.

GENERAL DESCRIPTION.

The steel frame is an oblong dome,—if such an expression can be used,—and, in this connection, presents some possibly novel features in it's construction.

In plan the structure has a straight portion 110 feet long, with semicircular ends, the width being 186 feet 2 inches back to back of arches, and the length 298 feet 2 inches. (Plate I.)

Filling in between these circular ends and the brick walls of the building there are floors, supported on cast iron columns and I beams, which, as they present nothing but ordinary building construction, will not be touched upon further in this paper.

The four main trusses in the central part are three-hinged arches, 176 feet 6 inches in span, center to center of end pins, and 80 feet in height between pins. (Plate II.) They are spaced 36 feet 8 inches, center to center. Above the main floor line, the panel points on the bottom ribs of the arches are on the curve of a true ellipse.

The radial, or cripple trusses, of which there are six at each end, are attached at their upper ends, by means of pins, to a half ring 12 feet in diameter, which, in its turn, is connected, by a pin at each end, to the end main trusses. These radial trusses would be just half of the length of the main arches were they not intercepted by this ring. (Plate III.) The ring is designed so as to

*Manuscript received April 11, 1898.—Secretary, Ass'n of Eng. Socs.

take up thrust only, and not any vertical reaction. The radial trusses cannot therefore exert any vertical reaction on the main trusses.

The roof covering, which is of an asphalt composition, is laid on 1$\frac{3}{8}$-inch boards, resting on wood joists, 2$\frac{1}{2}$ x 16 inches, 3 feet apart and ceiled underneath. These, in turn, are carried by the steel purlins of the structure, which are spaced about 16 feet apart.

The gallery floor banks are carried on stringers of 8-inch channels spaced 3 feet 8 inches, center to center, carried by girders running between, and supported by, the arches. The rear stringer is a plate girder; the front one is a latticed girder, the bank stringers running through the latter and cantilevering out 5 feet 4 inches. (Fig. 1.)

The main floor banks, consisting of 9-inch I beams, spaced 3 feet 8 inches, center to center, are similarly carried on girders, and their lower ends rest on a brick wall, which forms one side of the air conduit.

The foot of each arch rests on a 4$\frac{7}{16}$-inch pin, carried in a cast shoe, inclined so as to transmit the horizontal thrust to the footing, there being no bottom tie-rods. (Fig. 2.)

The entire load of the structure, therefore, is carried to these footings, excepting the small part of the main floor banks, which is supported by the brick wall before mentioned.

An interior view of the completed structure is shown in Fig. 4.

LOADS.

The loads, in accordance with which the stresses were figured, are as follows:

LOADS ON TRUSSES.

Case I.

Wooden deck and gravel of roof........	17.5	lbs. per sq. ft.,	vertically.
Steel....................................	12.5	“ “ “ “	“
Snow and wind........................	25.0	“ “ “ “	“
Total	55.0	“ “ “ “	“
Add for floors, viz—			
Main floors, banks and galleries.........	105.0	“ “ “ “	“
Attic floors.............................	60.0	“ “ “ “	“

Case II.

Wooden deck and gravel of roof........	17.5	lbs. per sq. ft.,	vertically.
Steel....................................	12.5	“ “ “ “	“
Snow	10.0	“ “ “ “	“
Total	40.0	“ “ “ “	“
Wind pressure over entire elevation of wall and roof of.....................	30.0	lbs. per sq. ft.,	horizontally.

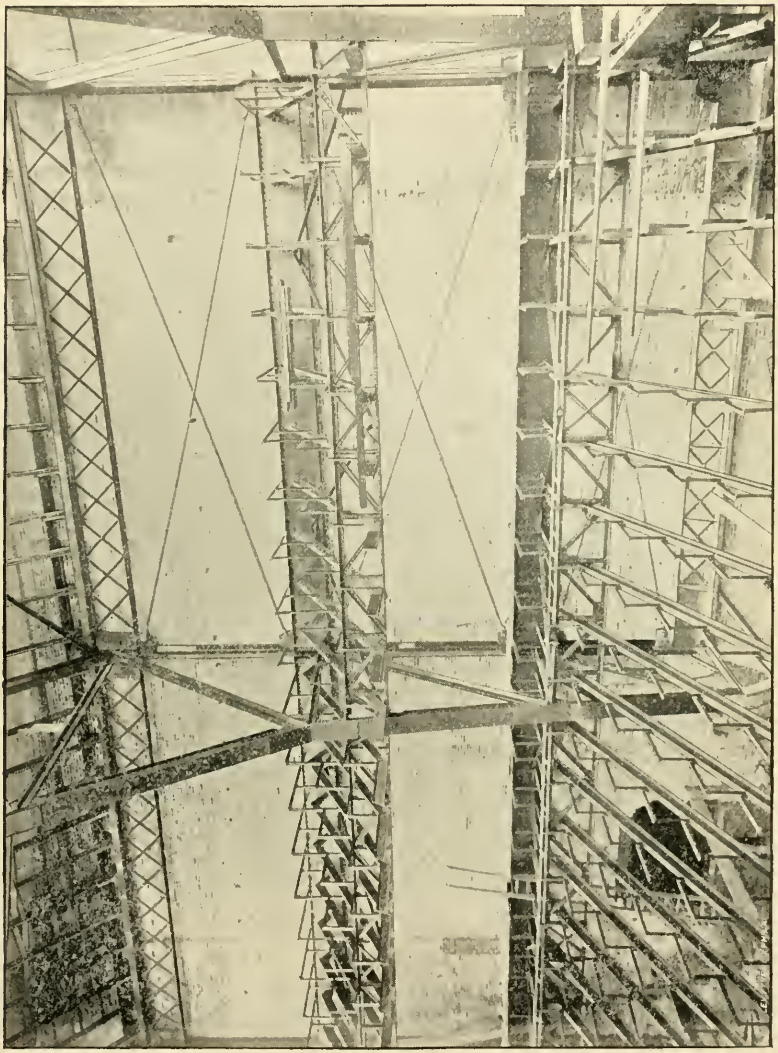


Fig. 1. Bank Framing.

LOADS ON PURLINS.

Wooden deck and gravel of roof	17.5	lbs. per sq. ft.,	vertically.
Steel	3.5	" " " "	"
Snow and wind	25.0	" " " "	"
Total	46.0	" " " "	"

LOADS ON FLOOR BEAMS, GIRDERS AND COLUMNS OF MAIN FLOORS.

Banks and galleries, beams	140	lbs. per sq. ft.
" " " girders	112	" " " "
" " " columns	105	" " " "
Attic floors, beams, columns and girders	60	" " " "

For the main trusses, in addition to the stresses of Case II, there was added the stress due to the wind bracing between these trusses.

For the radial trusses, in addition to loading of Case II, there was assumed an additional load of 50,000 pounds supposed to act up or down at the upper point of truss; this load being what was assumed probable in case there was slight unequal settlement of the footings.

For the half ring connecting the tops of the radial trusses there was another case assumed, beside Cases I and II,—viz, a thrust of 50,000 pounds at any point of the half ring; this being the thrust of a radial truss under its full live and wind load.

MATERIAL AND WORKMANSHIP.

Materials. All the material used was of medium steel, excepting the rivets, which were made of soft steel. Both material and workmanship conform to Manufacturer's Standard Specifications.

UNIT STRAINS.

Tension	16,000	lbs. per sq. in.
Compression, for lengths of 90 radii or under	12,000	" " " "
" " " " over 90 radii	$17{,}100 - 57\frac{l}{r}$	
Combined stress due to tension or compression and transverse loading	16,000	" " " "
Shear on web plates	7,500	" " " "
Shear on pins	11,000	" " " "
Shear on rivets	10,000	" " " "
Bearing on pins	22,000	" " " "
Bearing on rivets	20,000	" " " "
Bending, extreme fiber of pins	25,000	" " " "
" " " " beams	16,000	" " " "

Lateral connections have 25 per cent. greater unit strains than the above.

The above unit strains are not to apply, however, to Case II of trusses. For this loading the above unit strains were increased one-third.

The maximum sections found by using the foregoing loading and unit strains were adopted for dimensioning members.

DETAILS OF CONSTRUCTION.

The ribs of the main arches are built of angles and plates in the form of a T section. The compression ribs have a cover plate and also a pair of light angles to stiffen the fin of the projecting

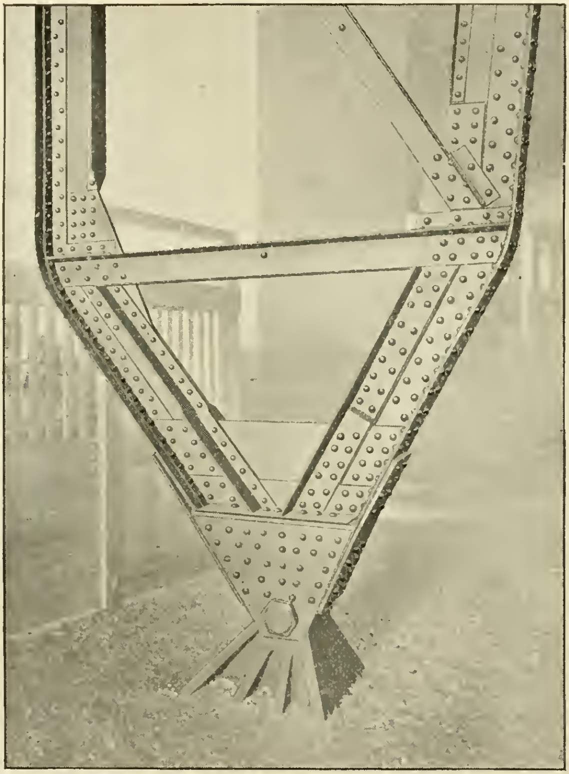


Fig. 2. St. Louis Coliseum, Pedestal and Foot of Arch.

web. The ribs of the radial arches, up to the haunch, are similarly constructed, except that the sections are lighter. From the haunch to the apex they are made of a pair of angles with cover plates.

The web members are all made of angles. The joints are all full-riveted, no allowance being made for abutting in the compression ribs.

The purlins are triangular trusses $4\frac{1}{2}$ feet deep, made of angles. (Plate IV.)

The half ring (Plate IV) is made of a pair of 7 x $3\frac{1}{2}$-inch angles, with web members of 3 x 3-inch angles. At each end it connects, by means of horizontal pins $3\frac{15}{16}$ inches in diameter, to the end main truss. The radial arches are connected to this ring by horizontal pins $2\frac{7}{16}$ inches in diameter. For convenience in supporting it during erecting, and for the sake of appearance, this radial ring has a light framework of angles underneath. It is purely false work, and transmits no stress.

The laterals between the main trusses are 5 x 3 x $\frac{3}{8}$-inch angles above the haunch; all other laterals are rods having adjustment.

The inner girders, between the arches supporting the stringers of the gallery and main floor banks, are of latticed construction, with panel points the same distance apart as the stringers. They have an upright angle at each panel point, to which the stringers passing through the girders connect. (Fig. 1.)

All connections throughout the entire structure were riveted as far as possible, except, of course, at the expansion joints.

BRACING, ETC.

Under uniform vertical live or dead load, the resultant thrust of one of the domed ends, at the top of the arches, would be counteracted by that of the other end; but under unequal loading or wind pressure, which is assumed to act horizontally, the thrust, not being counterbalanced, has to be taken care of. For this purpose the main arches are coupled together in pairs with an efficient system of lateral bracing, one-half the thrust being supposed taken care of by each system. To properly transmit the thrust to these lateral systems, the top purlins, on each side of the ridge, are coupled together with brace rods, struts and X frames. For the sake of appearance, they are made the full depth of the arches.

The lateral rods do not run to the shoes, on account of the space at bottom of main trusses being required for stalls. A heavy portal, of triangular box section, carries the thrust down to the shoes.

The cripple trusses are coupled together in pairs with lateral rods down to the ceiling line. The thrust due to wind was then allowed to go into the line of girders around the structure at this point, and into the adjoining floor systems.

The compression ribs of the main and cripple arches are stayed against side motion by angle iron ties, connecting to the first panel-point in the bottom chord of the purlins.

Owing to the greater depths of the arches near the haunch, it was thought that this would not have been sufficiently effective.

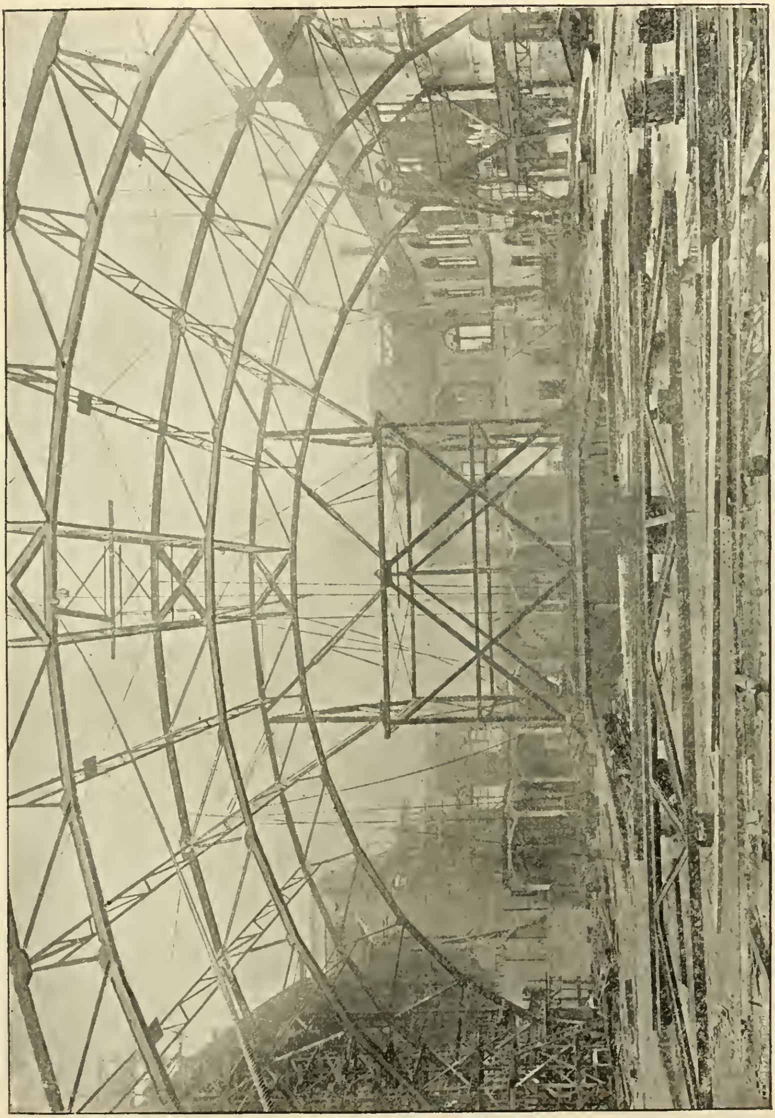


Fig. 3. St. Louis Coliseum During Erection.

Therefore, in the plane of the first diagonal brace of the truss above the haunch, diagonal rods are used, connecting all the bottom ribs of the trusses to the upper ribs of the next truss. No strut was used between the bottom chords, as it would have been directly in the line of vision from the rear gallery seats to the farther end of the arena.

The front and rear girders supporting the gallery and main floor banks are tied together with a triangular system of angle iron bracing, taking care of any local vibration, and firmly holding together the lower portions of all the arches.

EXPANSION.

To provide for expansion, the purlins and girders between the arches have slotted holes in every alternate bay, except that between the main arches there is no allowance for expansion in the purlin system, as the purlins have to act as struts for transmitting the resultant of half of the thrust of the radial arches to the two wind systems. As there is no likelihood of a greater variation in temperature than 75°, which would mean an extension of about three-quarters of an inch in 110 feet, or three-eighths of an inch at each end, this is taken care of by the slotted holes in the adjoining purlins of the radial system. The ties, from the purlins to the bottom chords of the arches, have no expansion joints, nor has the bottom chord of the purlins; but, the pair of upright angles of the arches not being connected together, where the bottom chord of the purlins attach to it, they can close together or spring apart sufficiently to take care of the small variation of less than one-quarter of an inch due to expansion in the purlins.

The rods, connecting the pair of ridge purlins between the tops of the main arches, were not adjusted until the conditions were favorable. A hot day was selected, when it was thought that the arch apex was at its highest point, the rods were then drawn taut.

As the temperature lowers, the arch lowers, and the rods become looser.

To prevent secondary strains in the half ring to which the radial trusses are connected at their tops, there is $\frac{1}{16}$-inch clearance in all the pin holes, where they connect with the rings, and also where the rings connect with the main arches. There is also clearance between the pin plates, so that the trusses and the ring can slide a little sideways on their pins.

SHOP CONSTRUCTION.

Before making the templates for the arches, the axial lines of a half arch were accurately calculated, and platted on the laying-

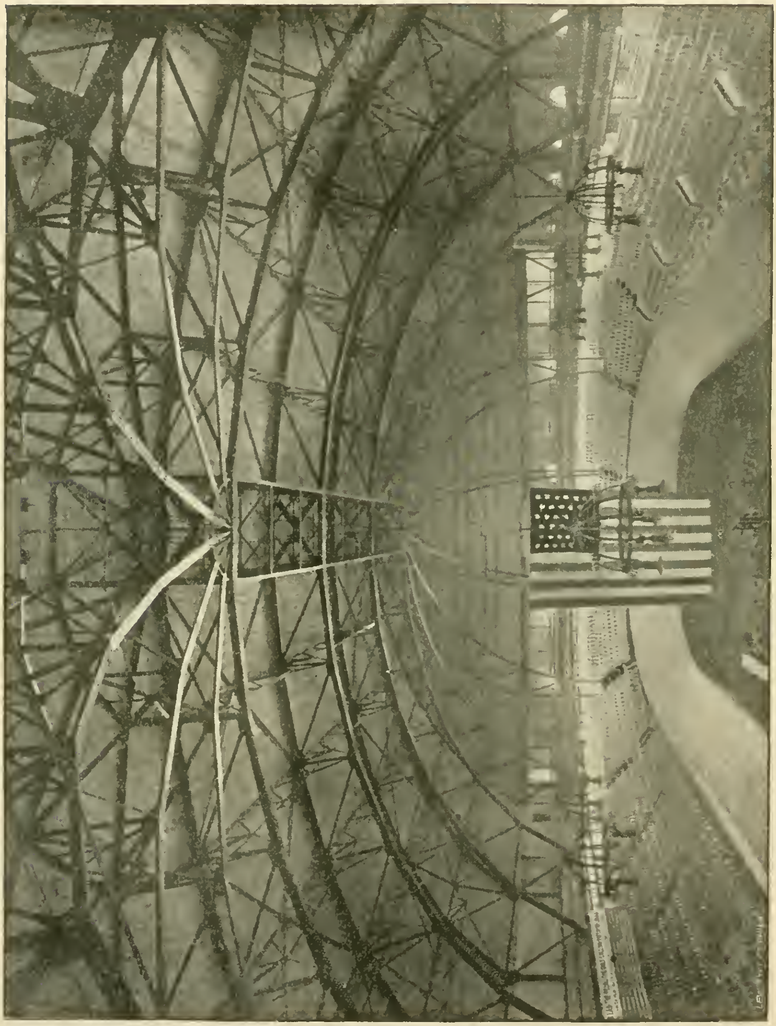


Fig. 4. St. Louis Coliseum—Interior after Completion.

out floor by triangular measurements. The extreme points of the lay-out were checked by independent measurements.

This full-size lay-out greatly facilitated the making of templates. Extreme accuracy in the matching of holes was insured with a minimum amount of draughting, and so nicely did the work come together that very little reaming was found necessary on assembling the pieces.

In order to avoid the handling of large, heavy pieces before the drill press, the foot of the arch, through which the pin hole was bored, was made separately, and afterwards riveted on.

ERECTION.

The wrecking and altering of the old interior of the building was carried on at the same time as the erection of the steel work.

Working in the building at the same time were wreckers, excavators, concreters, stone-masons, bricklayers, carpenters and pipe-fitters. Lumber and rubbish were piled everywhere. The confusion resulting from this state of affairs added materially to the cost of erecting, and impeded considerably the progress of the work.

It was, of course, absolutely necessary to locate the cast bases of the trusses very accurately, and it might be of interest to explain the method used by the writer.

It was found advisable to do this work on a Sunday, as no one else was then working on the building, for on a weekday it was very risky. One did not know just when a brick or a plank from aloft might hit him.

The shoes for the radial trusses being situated on the arc of a circle, hubs were located with the transit at the intersections of the tangents to the circle, passing through the axis of the pin of each truss. (Plate I.) The transit being then set up over these points successively, other hubs were then placed exactly 6 feet each side of the center of the arch and in the line of this tangent, and were sawn off so that their tops were at the same level as the center of the shoe pin. (Plate IV.)

A wire was then stretched between the tacks of these hubs and touching their tops, so that this wire coincided exactly, as to line and level, with the axis of the shoe pin.

A half pin of wood, with the center lines marked each way, and of the same size as the steel pin, being then placed in the cast base, it was an easy matter to bring the base into exact position.

Cast blocks and double wedges were used under each corner of the shoe, so that it could be readily raised or lowered.

When the shoes were brought into exact position, they were firmly stayed against any possible jarring during the erection of the arches by shoring against the sides of the pit.

During erection, the material was unloaded on the Fourteenth street end of the building by means of a boom derrick, which swung the material from the drays on to the old main floor of the building. It was skidded on rollers as nearly as possible to where it was wanted.

The bottom section of the arches came from the shop riveted up. These were set in position, with ordinary shear-leg derricks, from the old main floor of the structure.

The girders supporting the main and gallery stringers, being put in place, held them sideways. In the other direction they were shored up from the old floor.

The sections of the half arch, from the haunch to the apex, were then assembled on the old floor and riveted up complete. Timbers being lashed for stiffness, they were then tilted up on edge by means of the traveler derricks and a shear-leg, and then hoisted bodily into place by the traveler derrick.

This traveler was 63 feet wide, 31 feet deep and 42 feet high. It had two stiff leg-boom derricks on top, the mast being $24\frac{1}{2}$ feet long and the booms 34 feet long. (Fig. 3.)

The hoisting was done with a $\frac{5}{8}$-inch steel cable rove through double blocks on the falls, and passing down to a double-drum hoisting engine on the rear end of traveler. The boom falls were $1\frac{1}{4}$-inch hemp rope, rove through triple blocks, and were worked by a hand crab lashed to the floor of the traveler.

The radial trusses at the east end were raised by this traveler, as it faced that way; but at the west end only the two outside trusses could be handled by the traveler, the others being hoisted into position by means of a shear-leg derrick having a pole lashed to it.

WEIGHTS, ETC.

There were 76 sheets of shop details.

The total weight of the iron in the entire structure was 1,905,000 pounds.

Main arch	each	64,000	lbs.
Radial arch	"	21,000	"
Purlin between main trusses	"	1,450	"
Main floor bank stringer	"	810	"
Balcony floor bank stringer	"	280	"
Cast shoe	"	3,000	"

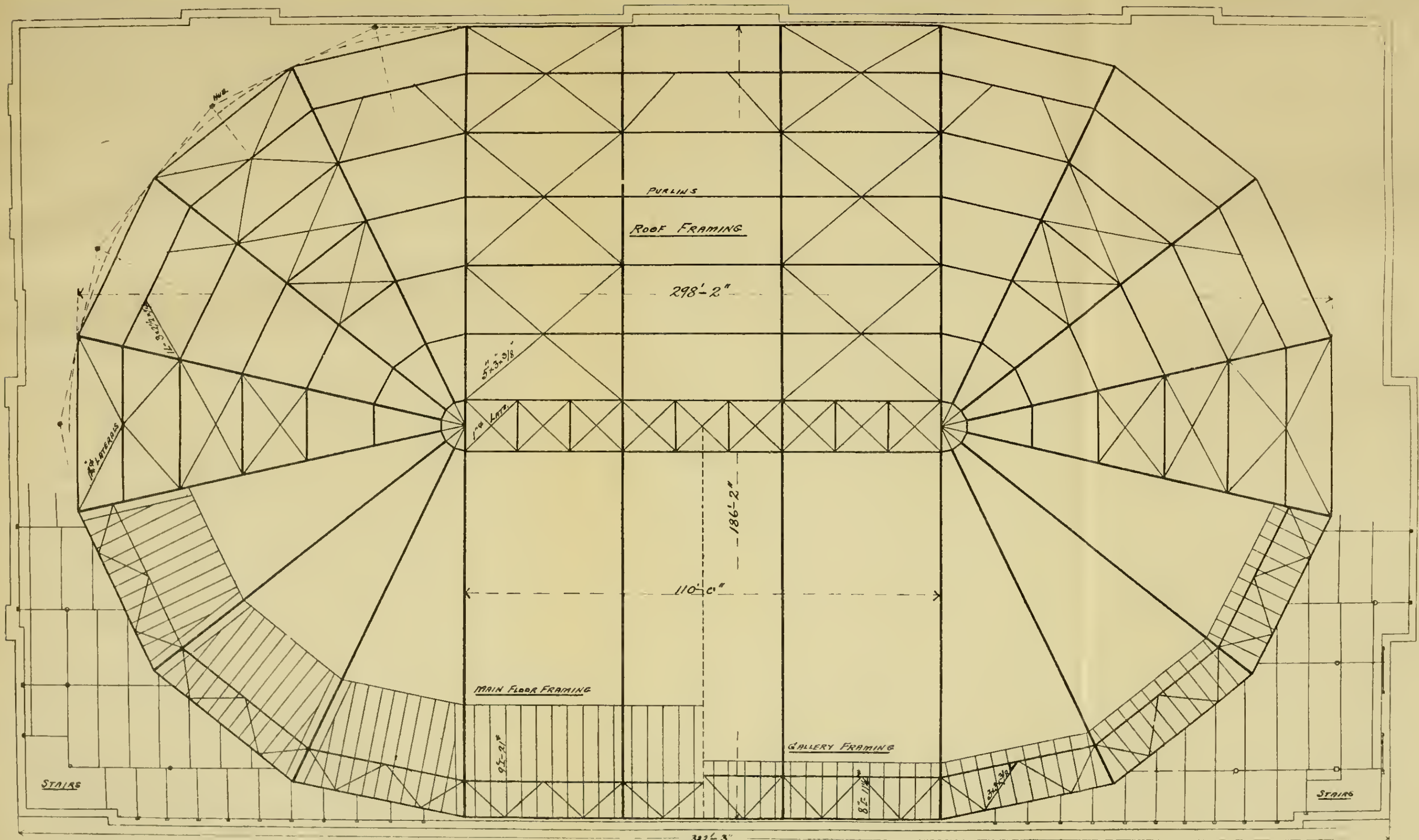
There were 4188 days' labor spent on the work in the shop and 3550 days' labor during erection, the average number of men in the erecting force being about fifty.

The stress diagrams and detail plans of the steel frame were made under the supervision of the writer, in the office of the Koken Iron Works, who were contractors for the ironwork, and were submitted for approval to the consulting engineer, Mr. Julius Baier, Assoc. Mem. American Society Civil Engineers, to whom the writer is indebted for valuable suggestions that were embodied in the construction.

The stress diagrams were also submitted for approval to the Board of Public Improvements, Mr. A. H. Zeller, engineer.

The shop work was inspected by Mr. J. D. McKee, civil engineer. The architect of the coliseum was Mr. C. K. Ramsay, consulting architect Mr. Louis H. Sullivan.

The general contractors for the entire structure were the Hill-O'Meara Construction Company.


HUB
PURLINS
ROOF FRAMING
298'-2"
186'-2"
110'-0"
MAIN FLOOR FRAMING
GALLERY FRAMING
STAIRS
STAIRS
322'-3"

—PLAN—

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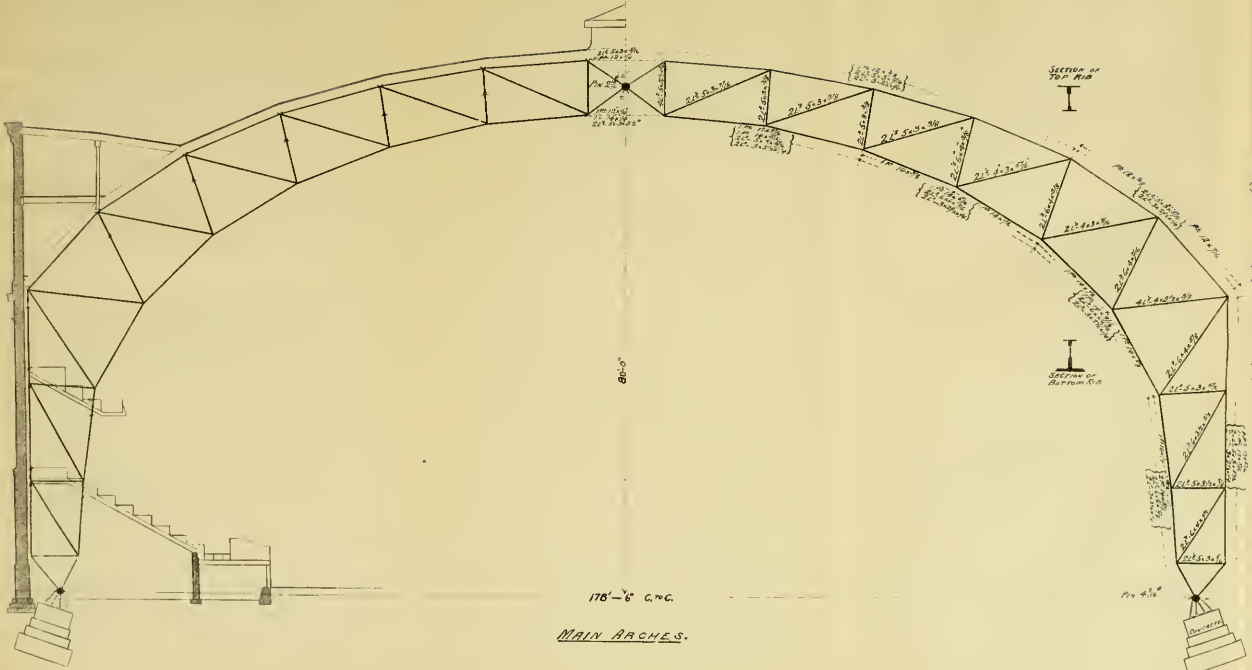
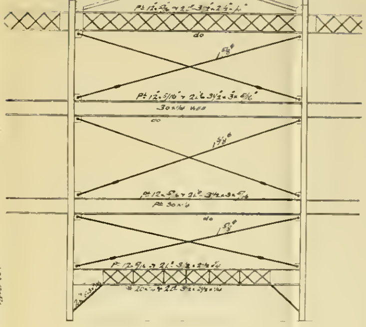
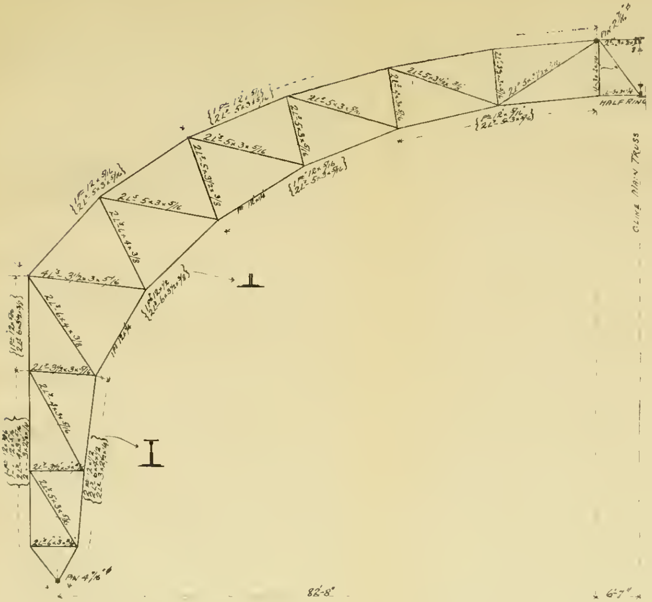


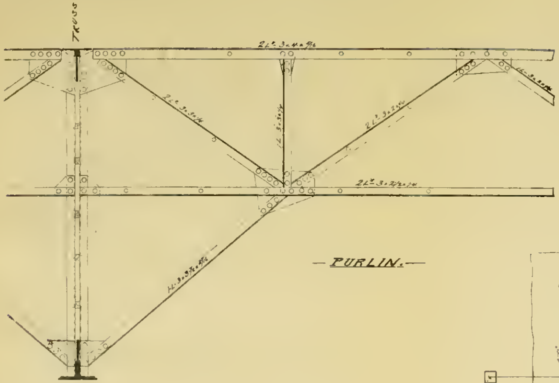
MAIN ARCHES.



BRACING BET. MAIN ARCHES.



RADIAL ARCH.



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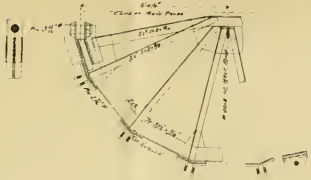
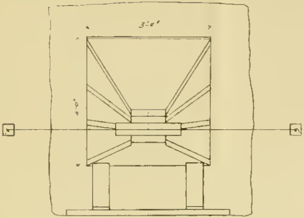
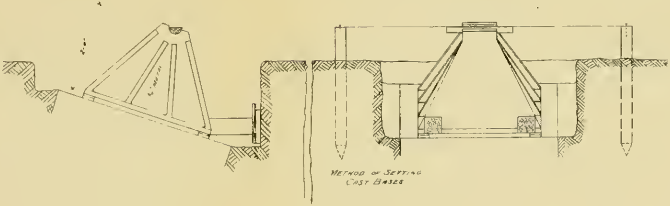


PLAN OF HALF RING CONNECTING RADIAL TRUSSES TO MAIN TRUSSES





METHOD OF SETTING CAST BASES

Editors reprinting articles from this journal are requested to credit both the JOURNAL and the Society before which such articles were read.

ASSOCIATION

OF

ENGINEERING SOCIETIES.

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CO-ORDINATE SURVEY OF THE CITY OF BOSTON.*

BY FRANK O. WHITNEY, MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Society, May 18, 1898.†]

DURING more than two hundred and fifty years of its history Boston has suffered great inconvenience and expense, owing to the complexity of its street system and the great outlay of money and the destruction of property necessitated by frequent attempts to widen and improve her thoroughfares.

From year to year the difficulties have increased by reason of a condition which allowed owners of property to develop it in any way which might suit their convenience without municipal control.

Appreciating the complications likely to arise from a continuance of past methods the Mayor of Boston, in 1891, presented a bill to the Legislature which resulted in an act providing for the appointment of a Board of Survey for the city of Boston with authority to devise a scheme of streets for the entire city, to be adopted as a basis for future street improvements.

The act also provides for changes in the methods of procedure in assessing the cost of street construction.

*The writer desires to express his obligation to Mr. S. C. Ellis, who was Chief Engineer for the Board of Survey from 1891-1895, and to Mr. J. Frank Williams, engineer in charge of the triangulation, for information either directly or indirectly received in regard to the earlier work of this survey.

The annual reports have been freely quoted without particular acknowledgment.

†Manuscript received May 26, 1898.—Secretary, Ass'n of Eng. Socs.

The duties of the Board of Survey, as defined by the act, are as follows, viz: "The Board of Survey shall, with all reasonable dispatch, cause to be made under its direction plans of such territory or section of land in said city as said board may deem necessary, showing thereon the location of such highway or the location of such highways, whether already laid out or not, as said board shall be of the opinion the present or future interests of the public will require in each territory, showing clearly the directions, widths and grades of each highway."

That the board might be able to present their views to the public, and at the same time get a general expression of the opinion of all public-spirited citizens as to the future needs of the several sections of the city, preliminary plans covering large territories were compiled and plotted on a scale of one in one thousand.

While these plans were not the result of actual survey they were of sufficient accuracy to permit of their use at public hearings, and have been most valuable for the purpose of blocking out preliminary systems of streets.

These plans are publicly displayed and have been of great value to the department, especially when called upon to furnish general information regarding the work.

At the outset it became necessary to determine what means should be used to accurately and permanently locate streets to be projected in compliance with the act.

It had been the custom to depend largely upon offsets to substantial buildings for the location of street lines in the more thickly settled portions of the city, and where no convenient objects of that nature were accessible, to depend either upon offsets to fences or cause ordinary stone bounds to be placed in the ground.

Experience has proved that these methods do not necessarily secure permanence, as in the continual changes due to reconstruction and other causes, many monuments become unreliable or are totally destroyed.

In case of a fire sweeping over a large area, as in the great fires of Boston and Chicago, a vast number of boundaries become totally obliterated, and much litigation naturally follows.

After careful consideration of the advantages and disadvantages of different methods of location, it was decided to adopt a system of location by rectangular co-ordinate positions determined with reference to two imaginary lines at right angles to each other, and passing through the center of the dome of the State House as an initial point, the position of which had been determined by the

United States Coast and Geodetic Survey. By so doing direct connection with the Government surveys was secured.

The whole city was then blocked into squares of 10,000 feet on a side by lines parallel with and at right angles to the State House meridian, each square being designated by a letter.

These squares were then subdivided into one hundred smaller squares with 1000 feet on a side and numbered from one to one hundred.

The official plans filed include the area covered by each one of these smaller squares, and are designated by letters and numbers as A 1, X 10, etc.

These plans, when completed, are filed with the City Engineer, and by reference to an index map the location of each plan may be seen and the progress of the work readily noted.

The distance of each section line from the State House meridians is given upon each plan.

The azimuths of all street lines from the State House meridian are shown on the plan, and the co-ordinate positions of the street corners and tangent points of curves are also given.

With this data, the position of any point, or the distance between any two points, may be readily calculated.

For the preservation of lines and the convenient establishment of the points on the ground, monuments set in concrete have been placed at frequent intervals and their location designated on the plans by their co-ordinate positions.

The surveys have been very carefully made. The most approved methods have been adopted, and a high degree of accuracy has been attained.

The survey is based upon a triangulation in which positions determined by the United States Coast and Geodetic Survey were used as primary points from which secondary stations were located by means of a system of triangles which extended over the whole city.

These secondary positions are located upon prominent points throughout the city, and from these other points have been transferred at frequent intervals to the ground.

These last-named points have been a basis for traverse measurements and connections.

The primary bases for this triangulation were obtained from Appendix 8, Coast and Geodetic Survey Report for 1885.

The points used and their geodetic positions are as follows:

Name of Station.	Latitude.	Longitude.
Prospect, Waltham	42-23-18.831	71-15-15.333
Cambridge Observatory, center of dome, telegraphic longitude station, 1851 and 1872	42-22-53.490	71-07-43.885
Boston State House (C. & G. S & B.)	42-21-29.596	71-03-51.040
Blind Asylum	42-20-07.037	71-02-32.861
Blue Hill, astronomical azimuth station, 1845	42-12-43.941	71-06-52.638
Powderhorn 2, 1877	42-24-04.564	71-01-52.055
Nantasket	42-18-15.69	70-54-20.203

Of these points Blue Hill is the only primary position accessible for purposes of this survey, the next nearest being Wachusett. Its position can be relied upon with almost absolute accuracy.

Nantasket is a sub-primary station, and its position is considered very accurate.

Prospect Waltham is a principal secondary station, and its position is nearly as accurate as Blue Hill.

Cambridge Observatory is a secondary station; its position is considered good but inferior to Prospect Waltham.

The State House and Powderhorn are tertiary positions, possessing about one-half the accuracy of Prospect Waltham.

The Blind Asylum is also a tertiary position, but for it the Government makes no claim for accuracy.

The bases were computed by inverse solutions of the "Latitude, Meridian and Azimuth" formulæ. See Clarke's formulæ, Appendix No. 7, Report for 1884, United States Coast and Geodetic Survey.

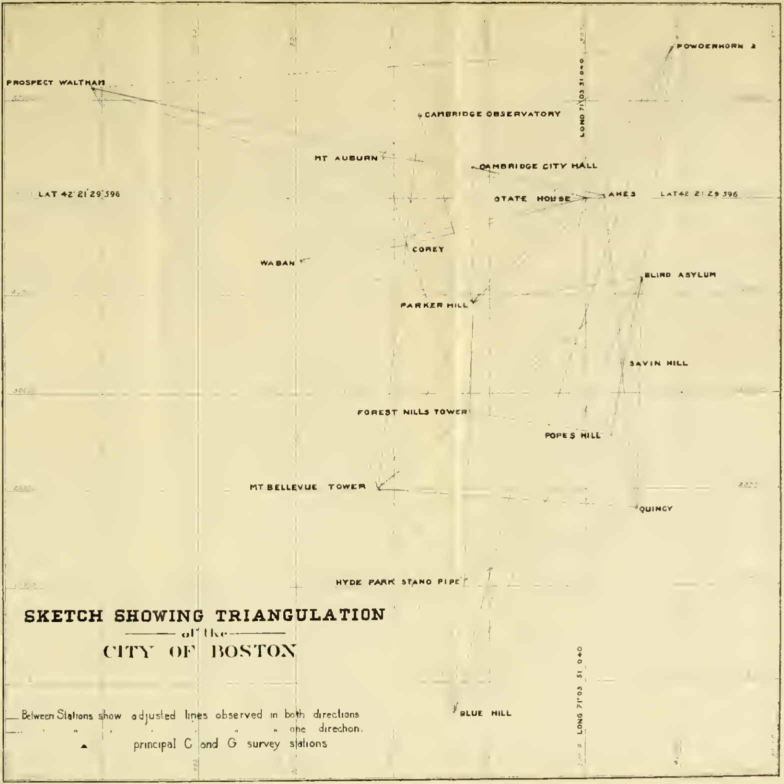
From State House to	Distance. Meters.	Log. Meters.	Distance. Feet.	Log. Feet.
Prospect Waltham	16015.11	4.2045299	52543.48	4.7205188
Cambridge Observatory,	5923.29	3.7725628	19433.53	4.2885517
Blind Asylum	3113.08	3.4931908	10213.62	4.0091797
Blue Hill	16744.16	4.2238634	54935.41	4 7398523
Powderhorn 2	5502.11	3.7405295	18051.71	4.2565184
Nantasket	14373.68	4.1575679	47158.16	4.6735569

For convenience the zero of the system of rectangular coordinates was assumed 50,000 feet south and 50,000 feet east of the position of the State House, thereby avoiding minus positions, only four of which occur in the system, viz:

Blue Hill, astronomical azimuth station, 1845.

Blue Hill, Borden triangle let into floor inside of tower.

Blue Hill pole, flagstaff on top of tower.


POWDERHORN 2
PROSPECT WALTHAM
CAMBRIDGE OBSERVATORY
LONG 71°03 31 040
MT AUBURN
CAMBRIDGE CITY HALL
LAT 42° 21' 29" 596
STATE HOUSE
AMES
LAT 42 21 29 596
COREY
WABAN
BLIND ASYLUM
PARKER HILL
SAVIN HILL
FOREST HILLS TOWER
POPES HILL
MT BELLEVUE TOWER
QUINCY
HYDE PARK STAND PIPE
SKETCH SHOWING TRIANGULATION
of the
CITY OF BOSTON
BLUE HILL
Between Stations show adjusted lines observed in both directions
" " " " " " one direction.
principal C and G survey stations

Na
Prospect, Wa
Cambridge C dome, teleg 1851 and 18
Boston State
Blind Asylum
Blue Hill, ast tion, 1845...
Powderhorn
Nantasket....

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Blue Hill tower, center of tower.

The geodetic position of the State House was assumed as the center of the system, and the geodetic azimuth and bases obtained from the inverse solutions of the L. M. Z. of Clarke's formulæ were used to establish the co-ordinate positions of

Name of Station.	North.	West.
Prospect, Waltham	61115.46	101354.29
Cambridge Observatory	58499.41	67476.33
Blind Asylum	41643.17	44127.93
Blue Hill	—3208.32	63666.51

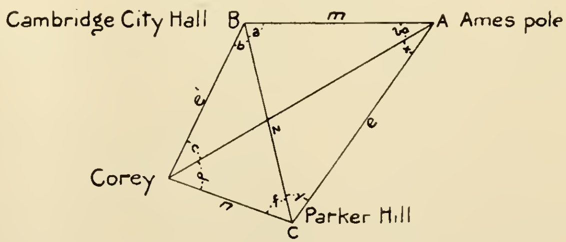
From these co-ordinate positions were obtained the azimuths and bases:

From	To	Azimuth.	Distance. Feet.	Log. Feet.
Prospect, Waltham	Cambridge Obs	274-24-56.18	33978.82	4 5312083
" "	Blind Asylum	288-47-30.45	60448.54	4.7813858
" "	*Blue Hill	329-38-01.10	74551.43	4.8724560
Cambridge Obs	Blind Asylum	305-49-37.86	28797.23	4.4593507
" "	*Blue Hill	356-28-01.40	61825.23	4 7911657
Blind Asylum	*Blue Hill	23-32-21.50	48922.52	4.6895088

The position of Parker Hill, Ames and Ames pole were then established, and the base, Parker Hill to Ames pole, was used by means of the "two-point" problem to determine the position of Cambridge City Hall and Corey, the formula for which was obtained from the Massachusetts Topographical Survey, being one which appeared in the manuscript report of Mr. James Main, of the United States Coast and Geodetic Survey in 1877.

The formula and its application is here shown:

TWO-POINT PROBLEM.



*Blue Hill, astronomical azimuth station, 1845.

Given angles a, b, c, d and side e

$$\frac{e'}{e} = \frac{e'}{m} \times \frac{m}{e} = \frac{\sin\ (a + b + c)\ \sin\ y}{\sin\ c\ \sin\ a} \qquad 1$$

$$\frac{e'}{e} = \frac{e'}{n} \times \frac{n}{e} = \frac{\sin\ b + c + d\ \sin\ x}{\sin\ b\ \sin\ d} \qquad 2$$

$$\therefore \frac{\sin\ y}{\sin\ x} = \frac{\sin\ a\ \sin\ c\ \sin\ (b + c + d)}{\sin\ b\ \sin\ d\ \sin\ (a + b + c)} = \tan\ \Phi$$

$$\therefore \frac{\sin\ y - \sin\ x}{\sin\ y + \sin\ x} = \frac{\tan\ \Phi - 1}{\tan\ \Phi + 1}$$

$$\text{or } \frac{\tan\ \frac{1}{2}\ (y - x)}{\tan\ \frac{1}{2}\ (y + x)} = \tan\ (\Phi - 45^\circ)$$

$$\text{but } \tfrac{1}{2}\ (y + x) = \tfrac{1}{2}\ (b + c)$$

$$\therefore \tan\ \tfrac{1}{2}\ (y - x) = \tan\ \tfrac{1}{2}\ (b + c)\ \tan\ (\Phi - 45^\circ)$$

$a = 78^\circ\ 21'\ 54.56''$	$b + c + d = 123^\circ\ 45'\ 26.43''$
$b = 37^\circ\ 44'\ 57.50''$	$a + b + c = 150^\circ\ 41'\ 20.73''$
$c = 34^\circ\ 34'\ 28.67''$	$\frac{1}{2}\ (b + c) = 36^\circ\ 09'\ 43.08''$
$d = 51^\circ\ 26'\ 00.26''$	log. $e = 4.2321670$

	log. sin a	9.9909835
	log. sin c	9.7539499
	log. sin (b + c + d)	9.9198092
co. log.	sin d	0.1068577
co. log.	sin b	0.2131012
co. log.	sin (a + b + c)	0.3102043
	tan Φ	0.2949058
	Φ =	$63^\circ\ 06'\ 37.45''$

tan ½ (b + c)	9.8638404
tan (Φ — 45°)	9.5146159
tan ½ (y — x)	9.3784563
½ (y — x)	$13^\circ\ 26'\ 35.83''$
½ y + x	$36^\circ\ 09'\ 43.08''$
x	$22^\circ\ 43'\ 07.25''$
y	$49^\circ\ 36'\ 18.91''$

log. e	4.2321670
sin (a + b + c)	9.6897957
sin y	9.8817257
co. log. sin c	0.2460501
co. log. sin a	0.0090165
e′	4.0587550

log. e	4.2321670
sin (b + c + d)	9.9198092
sin x	9.5868199
co. log. sin b	0.2131012
co. log. sin d	0.1068577
e′	4.0587550

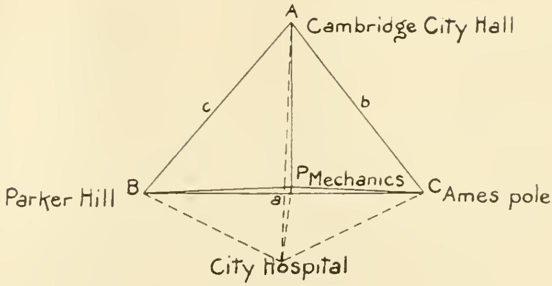
ANOTHER SOLUTION.

Assuming the side e′ as unity, the angles and sides of the quadrilateral may be computed as follows:

$180^\circ - (b + c + d) = f$	$180^\circ - (a + b + c) = g$
$\sin\ f : \sin\ (c + d) = 1 : z$	$\sin\ g : \sin\ c = 1 : m$

Which gives two sides and the included angle of the triangle A, B, C, from which we can find the angles y and (g + x) and their sides in relation to e′ as unity.

THREE-POINT PROBLEM.



The "three-point" problem has been employed very satisfactorily in the determination of positions; two independent solutions were always worked, and frequently three or four.

Reference is here made to Appendix 9, Report for 1882 of the United States Coast and Geodetic Survey, for a more comprehensive exemplification of the problem.

One example of its application is appended:

Given sides a, b and c.
Given angles A, B and C.
Observed angles A, P, C and A, P, B.

To find A, B, P = x	A, P, C = P′
To find A, C, P = y	A, P, B = P″

Azimuth Cambridge City Hall to Parker Hill..............	1° 17′ 21.03″
Azimuth Cambridge City Hall to Ames pole..............	228° 55′ 26.57″
Angle at A..	78° 21′ 54.46″

$$\tan Z = \frac{c \sin P'}{b \sin P''} \qquad e = \tfrac{1}{2}(x - y) \qquad \tan e = \cot (Z + 45°) \tan s$$

$x = s + e$

$y = s - e$; but if tan e be negative, then $x = s - e$ and $y = s + e$

$s = 180° - \tfrac{1}{2}(A + P' + P'')$

log. c	4.1229092	A =	78° 21′ 54.46″
sin P′	9.9997980	P′ =	91° 44′ 50.62″
co. log. b	5.8621092	P″ =	92° 55′ 53.23″
co. log. sin P″	0.0005687		2)263° 02′ 38.31″
tan Z	9.9853851		131° 31′ 19.15″
Z	44° 02′ 10.05″		180°
			48° 28′ 40.85″

log. cot (Z + 45°)	8.2259390
log. tan s	0.0528558
log. tan e	8.2787948
e	1° 05′ 18.93″
s	48° 28′ 40.85″
x	49° 33′ 59.78″
y	47° 23′ 21.92″

Ames pole to Cambridge City Hall		4.1229092
Mechanics	92° 55′ 53.23″	0.0005687
Ames pole	49° 33′ 59.78″	9.8814762
Cambridge City Hall	37° 30′ 06.99″	9.7844663
Mechanics to Cambridge City Hall		4.0049541
Mechanics to Ames pole		3.9079442

Parker Hill to Cambridge City Hall		4.1378908
Mechanics	91° 44′ 50.62″	0.0002020
Parker Hill	47° 23′ 21.92″	9.8668613
Cambridge City Hall	40° 51′ 47.46″	9.8157420
Mechanics to Cambridge City Hall		4.0049541
Mechanics to Parker Hill		3.9538348
Azimuth Cambridge City Hall to Ames pole		282° 55′ 26.57″
Angle at Cambridge City Hall, Ames pole to Mechanics		37° 30′ 06.99″
Azimuth Cambridge City Hall to Mechanics		320° 25′ 33.56″

9.8869430	sin 320° 25′ 33.56″ ... cos	9.8041902
4.0049541	Mechanics to Cambridge City Hall	4.0049541
3.8918971		3.8091443
7796.45		6443.83
53246.49	Cambridge City Hall	61364.12
45450.04	Mechanics	54920.29

This presents one of the four solutions worked. The four results and their mean are:

	North. feet.	West. feet.
Cambridge City Hall, Ames pole, Parker Hill	45450.04	54920.29
Parker Hill, Ames pole, City Hospital	45450.02	54920.31
Cambridge City Hall, Ames pole, City Hospital	45450.04	54920.32
City Hospital, Parker Hill, Cambridge City Hall	45450.00	54920.29
	4).10	4)1.21
Mean position of Mechanics	4545.02	54920.05

When the several determinations of the co-ordinate positions have approximated closely, the final result has been obtained by using the arithmetical mean instead of the process of least squares, the result showing no appreciable difference.

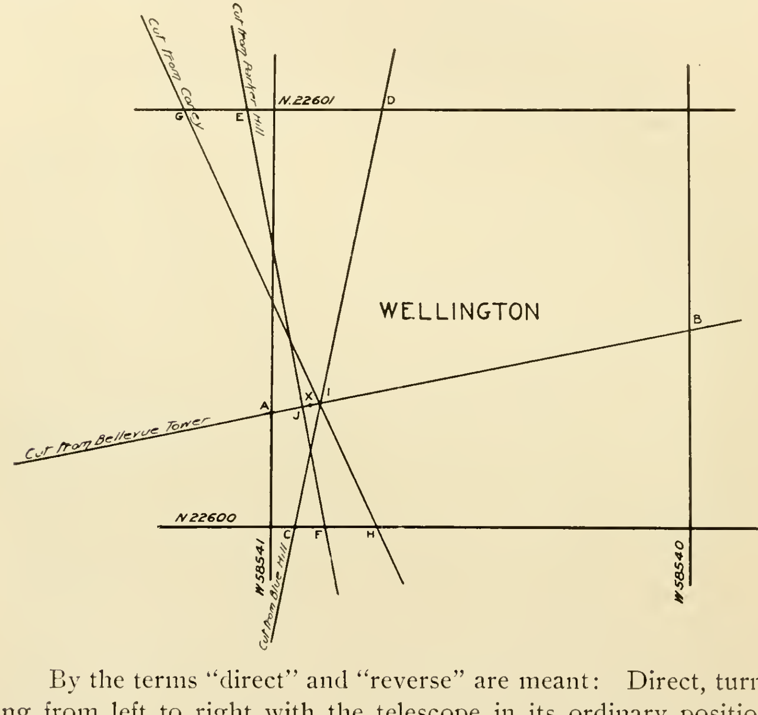
In the more recent work, it has been found convenient to plot the several determinations on a scale of one to one and decide upon a mean graphically.

This is illustrated in the figure.

A and B show where the line from Bellevue Tower crosses the meridian lines W. 58541 and 58540. C and D show where the line from Blue Hill cuts the Lines N. 22600 and N. 22601. E and F show the intersections of the line from Parker Hill, and G and H the intersection of the line from Corey.

These positions plotted full scale show intersections at I and J, whose mean may be readily seen to be at X, the north and west ordinate of which may be measured.

The angles observed for fixing co-ordinate positions were read twenty-four times or more, twelve direct and twelve reverse, turning from left to right.



By the terms "direct" and "reverse" are meant: Direct, turning from left to right with the telescope in its ordinary position (with level bubble below telescope). Reverse, reversing the telescope and repeating the operation.

This was done for the purpose of correcting any error in the line of collimation.

The readings were taken by the continuous method to avoid errors of graduation.

First setting the plates at zero, sighting to the left-hand signal, and clamping the lower motion; releasing the upper motion and turning to right-hand signal and clamping.

This angle was read and called the rough angle, or 1, as it appears in the form here shown; the lower motion was then released, telescope turned back to left-hand signal and the operation repeated, with the exception that no more readings were taken until the sixth angle had been turned. Readings of both verniers were recorded.

AT WATER-TOWER, DECEMBER 16, 1892.

Station.	Time.	D R	Rps	A	B	Mean of Vern'rs	Angles.	Mean of D & R	Remarks.
Blind Asylum,	9.30			360-00-00	180-00-00				Clear and Cold
			1	129-42-40		′ ″			
		D	6	58-16-30	238-16-30	16-30	129-42-45	129-42-45	
		R	6	116-33-00	296-33-00	33-00	129-42-45		
		D	6	174-49-30	354-49-30	49-30	129-42-45		
		R	6	233-06-00	53-06-00	06-00	129-42-45		

The operation of "filling the circle" has been strictly adhered to. For instance, if an angle of 90° was read from A to B, the angle from B to A, or 270°, was read with equal care.

In a circle comprising several pointings, as A, B, C and D, the angles A to C and B to D were also read for the purpose of eliminating possible error.

The transit was a Buff and Berger, with horizontal plate 7 inches diameter, graduated to 20′ with vernier reading to 10″. The cross-hairs in the telescope were placed at an angle of about 60°, with the horizontal in the form of an X, dispensing with the vertical hair. The weight of the instrument and tripod together is 26½ pounds.

Refraction was the most potent factor in delaying progress of the work. Numerous chimneys, ventilating shafts, etc., in the city proper gave a great amount of trouble to the observer, and required extreme care and patience in manipulating an instrument. Observations were taken at different hours of the day, and under different conditions of atmosphere, for the purpose of eliminating errors of refraction. In the suburban districts the refraction did not exist to the same extent, and the work progressed much more rapidly. Heliotropes were used on the long and difficult sights, and the stations were occupied several times.

The signals first used were of the tripod form; the center pole 10 feet long, 2½ inches in diameter, and painted alternately black and white each foot in length; the tripod or braces were 9 feet long by 2¾ inches, and secured by ¼-inch bolts to the center pole and to heavy stakes driven into the ground for the purpose. This form of

signal was found to be convenient, as no nails were required to put it in place. A small wrench was all that was required to remove a signal from over a station. These signals, however, in the later work have been superseded by poles 12 feet long and 4 inches in diameter supported by guy wires attached to the pole by means of screw eyes, and fastened to stakes in the ground. This form of signal is more easily transported from place to place, and is more simple in construction.

The next important work after the triangulation has been the survey of the territory under consideration. This work has involved the measurement and location of all objects on the ground, the determination of present street lines, and as far as property lines were affected by the proposed street widenings, or the location of new thoroughfares, the investigation of individual ownership.

This work has called for the greatest possible care in the measurement of lines, it being necessary that all surveys should fit into the triangulation. All base line measurements have been made upon the surface, and the correction for difference in level determined by leveling over the line with an instrument instead of trusting to the possibility of accuracy in making plumbed measurements. The temperature has been carefully noted, and the proper correction made. Balances have been used to determine the tension on the tape. The surveys have been plotted on a scale of 1 in 250. The working plans or plots thus made will become extremely valuable in the future, as they contain much information which it is impracticable to show on the finished plans. These plots show as fully as possible all information gathered from many sources, the results of calculations, the data from recorded plans and deeds, as well as interpretations of lines furnished by private surveyors.

After the annexation of the several cities and towns which now make up a large part of the city of Boston, surveys of the streets in each district were made, with reference to the existing objects. These surveys have been of great service in furnishing house and fence measurements, thereby saving a great deal of labor in connection with plan accessories.

These surveys have also been very useful in determining the acquirements by reason of occupation, as most of them were made prior to 1876. More than the twenty years required in most cases have elapsed, and these old notes furnish very valuable proofs of present ownership.

The street plans in the past have been very carefully made,

and their accuracy has not been impeached by this new survey; but as they have necessarily been the results of isolated surveys, except in a few cases where large sections have been considered, they cannot be depended upon for compilation into an accurate city survey, but they do become very useful in furnishing details for such a survey.

The rectangular system of laying out streets followed in New York, Philadelphia and many other cities has never found adherents in Boston, except for restricted areas like the Back Bay or for isolated sections as East and South Boston.

The old method of allowing each owner to develop his property in his own way has resulted in creating here and there small settlements which are scattered all over the city limits, planned without reference to each other and too firmly fixed to admit of radical change.

It has therefore been necessary to consider the existing conditions, and instead of obliterating streets that have been in use for a long time, to provide first for convenient thoroughfares and boulevards which shall connect these neighborhoods, and by providing the intervening spaces with streets arranged with reference to the topographical conditions and accessible to the main arteries.

The growth of Boston having been largely the result of annexation has been another reason for the present lack of system, and the necessity for allowing the general conditions to continue is apparent.

Again, the irregular outline of the city boundaries presents an obstacle to rectangular development which it is important to consider.

The selection of locations for main avenues is a comparatively simple matter, the main centers having been for the most part determined. The demand being for direct connection by means of avenues of sufficient width to accommodate all probable travel and of a gradient insuring economy and ease.

It has been necessary to provide for the widening of most of the streets which are destined to become the future arteries of the system.

A common width has been 80 feet. In some cases where the conditions point toward a large pleasure or street car travel boulevards 120 feet in width have been provided. On the other hand, many of the avenues have been laid down as narrow as 60 feet.

The streets off from the main lines of travel have been made for the most part 40 feet in width. In some cases 50 feet, and in neighborhoods where there seems to be no possibility of increased

use, the narrower existing streets have been allowed to remain without provision for future widening.

Topography has been such an important element in determining the locations of the streets that a great amount of contour work has been necessary. For this purpose it became important at the very beginning to do a large amount of leveling, all of which has been referred to the City Base as a datum plane.

The City Base was established as a plane of reference for city grades by the city engineer about fifty years ago, and until about twenty-five years ago was called mean low water, with which it was supposed to agree.

The point of reference all the time being the coping of the dry dock at the Charlestown Navy Yard, which was considered to be 15 feet above mean low water.

Coast survey observations covering a long period of time proved mean low water to be 0.64 feet above the City Base.

It was considered more convenient to continue the use of the old base with the new name than to change existing plans and grades to agree with the new determination of mean low water.

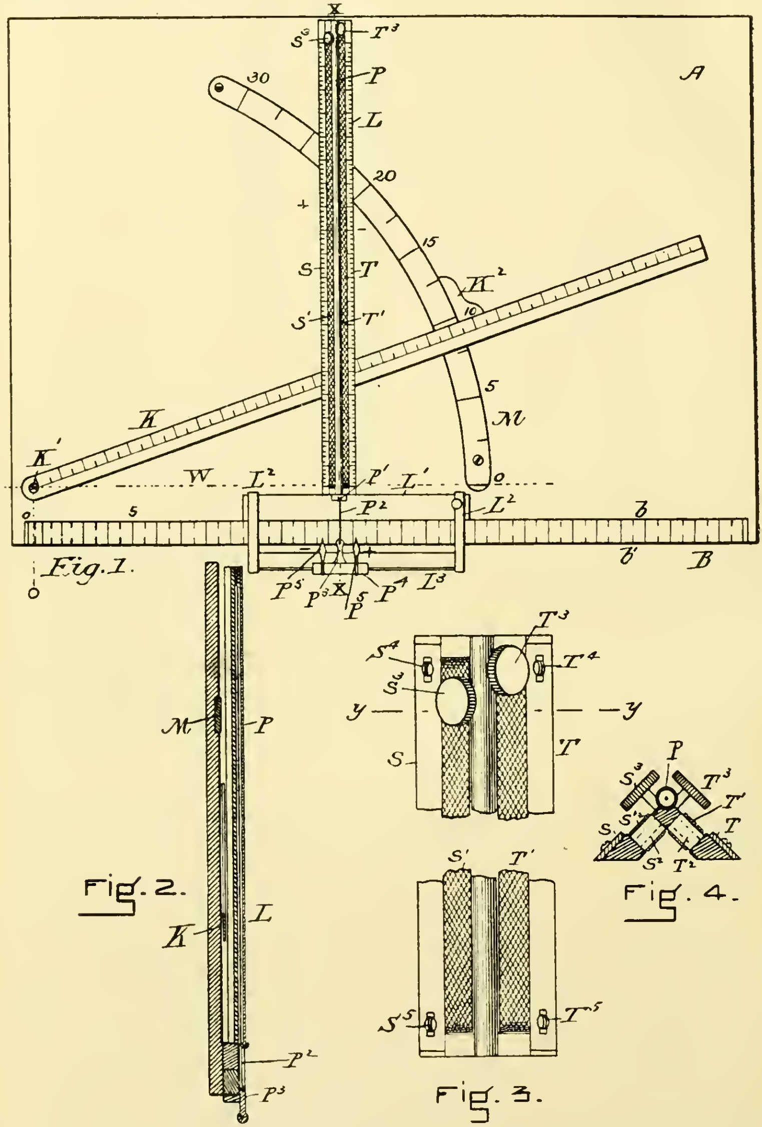
When the work of this survey was undertaken, in 1891, there were well-tested benches in existence in the various sections of the city, so that it was only necessary to extend the system, and in a few cases to test those which were of uncertain location or accuracy.

Profiles have been made of the main avenues from actual levels taken on the ground, but the profiles of the secondary streets have been made from the contour plans which have been the result of stadia work.

These contour plans of rough, undeveloped country have been of great use in determining both the location and proposed grade of each new street. The contours are shown for each foot of elevation, and the scale has usually been 40 feet to an inch. Previous to this survey very little accurate contour work covering large areas had been done by the city. The topographical plans in existence were so unreliable as to render them of little value in this work, although they undoubtedly answered the purpose for which they were made. The usual methods for performing stadia work have been adopted without discovering any special means of economizing labor in the field. Several methods of calculation have been tried, supplemented by the use of the mechanical devices which have found a place upon the market, none of which seemed entirely satisfactory.

The device which is now being used exclusively was invented

by Mr. William H. Foss, who has been connected with the survey from the beginning. It is simple in construction, its operation easily understood and the final results can be observed after three mechanical movements.



The apparatus is illustrated in the accompanying drawings, in which Fig. 1 shows the apparatus in plan. Fig. 2 is a section taken on line X X of Fig. 1. Fig. 3 shows in elevation parts of the vertical scale. Fig. 4 is a cross-section taken on line *y y* of Fig. 3.

Fig. 5 is an enlargement of a portion of the vertical device L and the reading-lines *b*, *b′* and K. The letters are the same as on plan, Fig. 1, except where new ones are required.

In the drawings, Fig. 1, A represents a base-board, made of any suitable material, and having fixed to its lower border a bar B, which has attached to it a scale-piece, upon both edges of which is

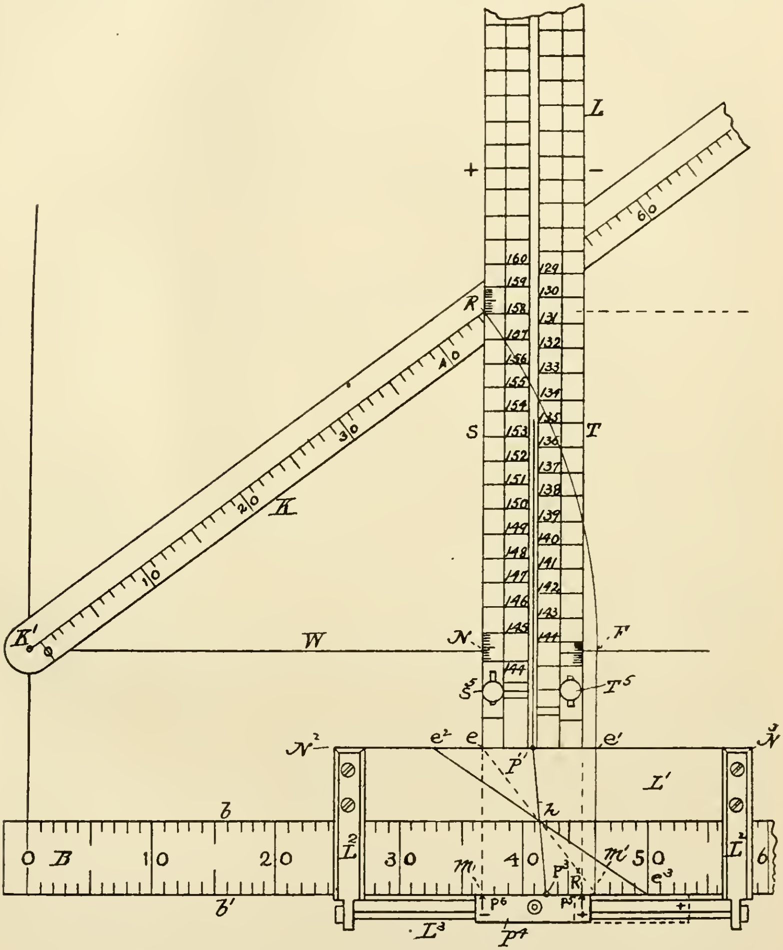


Fig. 5.

a graduated scale indicating feet or meters. These edges or reading-lines are indicated by *b* and *b′*, Fig. 1. The base A has also affixed to it, by a pivot at K′, a swinging arm K. This swinging arm is graduated with the same divisions that are upon the scales on the scale-bar B, but the zero-point on the arm is in advance of the zero-point on the fixed scales *b*, *b′*, as shown in Fig. 1. This

advance of the zero-point is made as a method of correcting the constant error made in measuring by stadia wires that is due to the fact that the intersection of the visual lines is not at the center of the instrument, but at a point in advance; that is, toward the object. As this correction varies with different instruments, the graduation marks are made on a movable strip adjustably attached to the swinging arm K. The swinging arm K has firmly attached to it a vernier K^2, graduated in the usual manner, and adapted to move with the swinging arm along the graduated arc M. The graduations and numbers on the arc M are so arranged that when the arm K is set so that the reading of the vernier is the same as the observed angle, the angle which the arm K makes with the scale *b* is twice the observed angle. The size of the graduations on the arc M is made double the size of ordinary graduations to the same radius.

The vertical device L, carrying the two scales S and T, Fig. 3, is attached to a sliding base-piece L′, which is free to move along the scale-bar B; and is so adjusted that the scales S and T will always be perpendicular to the scale-bar B. The base-piece L′ is held to the scale-bar B by the clamping pieces L^2, L^2. The vertical scales S and T are graduated just alike, and the unit divisions on them are twice as long as the unit divisions on the scales *b*, *b′* and K. The unit divisions on the scales S and T are subdivided to tenths of a unit division. The scales can be adjusted by means of the small clamp-screws S^4 T^4 and S^5 T^5 at either end of the scales, as shown on Fig. 3; so that any one of these tenth divisions of the first unit division may be made to coincide with the line W, passing through the point K′ and the zero-point of the arc M. Slots cut in the scales allow them to move back and forth a sufficient distance. There are no numbers on the scales S and T to designate the divisions, the numbering being done by two movable belt ribbons S′ T′, passing over small rollers S^2 T^2, Fig. 4, located at either end of the scales and running close to and parallel with said scales S and T. On the upper surface of these ribbons are numbers of any desired range. The rollers at the lower end of the scales are not shown, as they are the same as those indicated by S^2 and T^2 at the top of the scales, Fig. 4. The rollers S^2 and T^2 can be turned by means of the finger-wheels S^3 and T^3, so that the belt-ribbons can be moved in either direction and thereby cause any desired number to stand at any desired unit division of the scale S or T.

The reading-wire P^2 is an arrangement for the purpose of locating a point on the reading-line of the scale *b*, which point indi-

cates the reading of that scale to express the correct horizontal distance. It is attached to a flexible spring fixed within a tube P, said tube being located midway between the two belt-ribbons S′ and T′. The spring is for the purpose of keeping the reading-wire at a proper tension. The reading-wire P^2 passes through a small eyehole at P′. This eyehole is at a distance from the reading-line of the scale *b* equal to the distance between the reading-lines of the scales *b* and *b*′. After passing through said eyehole the end of the wire is attached near the center P^3 of a slide P^4. The slide P^4 moves on a spindle attached to the clamping-pieces L^2 L^2. On either side of the point P^3 are indexes P^5 P^6 at unequal distances from the point P^3, the distances depending upon the distance apart of the edges of the scales S and T and the constant correction before mentioned.

The apparatus, the several parts of which have been described, mechanically solves the two formulas

$$H = \frac{R + C}{2} + \frac{R + C}{2} \cos. 2\, n \qquad (1)$$

and

$$E = \frac{R + C}{2} \sin. 2\, n, \qquad (2)$$

in which H equals the horizontal distance from the center of instrument to the observed point. E equals the difference in elevation between the observed point and the station occupied. R equals the length of the intercepted portion of the stadia-rod multiplied by the instrument ratio. C equals a correction depending upon the instrument used to be added to R. *n* equals the observed angle of elevation or depression.

The usually accepted formulas for reducing stadia observations are

$$H = R \cos.^2 n + C \cos. n = \frac{R}{2} + \frac{R}{2} \cos. 2\, n + C \cos. n \qquad (3)$$

for horizontal distances and

$$E = \frac{R}{2} \sin. 2\, n + C \sin. n \qquad (4)$$

for the difference in elevation.

The formulas 1 and 2 are obtained from 3 and 4 by making an arbitrary change in both by adding the constant C to R and neglecting the term "C cos. *n*" in formula 3 and "C sin. *n*" in formula 4. The error introduced in the result by making this change can safely be neglected in this kind of work. The following table shows the amount of error made in horizontal and vertical distances for every five degrees up to twenty-five degrees by using formulas 1 and 2 instead of 3 and 4. The error made depends

wholly upon the angle of inclination and the correction C and is independent of the observed distance:

Data: R = 200.0 feet.
C = 1.25 feet.

Angle of inclination.	Horizontal distance		Elevation.		Error Made.	
	(3) formula.	(1) formula.	(4) formula.	(2) formula.	Horizontal distance, columns 2 and 3.	Elevation, columns 4 and 5.
1	2	3	4	5	6	7
5°	199.73	199.72	17.47	17 47	0.01	0.00
10°	195.20	195.18	34.42	34.42	0.02	0.00
15°	187.81	187.77	50.32	50.31	0.04	0.01
20°	177.78	177.71	64.71	64.68	0.07	0.03
25°	165.41	165.31	77.13	77.08	0.10	0.05

To simplify the writing of the formulas 1 and 2, make R + C = D. Then R will always stand for the observed distance, as determined by the rod reading, and D the total distance from the center of the instrument after the correction C has been added. Formulas 1 and 2 will hereinafter be written when referred to in the form

$$H = \frac{D}{2} + \frac{D}{2} \cos. 2\,n \tag{5}$$

$$E = \frac{D}{2} \sin. 2\,n. \tag{6}$$

There are three things to be proved in order to show that the apparatus does mechanically and correctly solve the two formulas 5 and 6. First, that the point on the reading-line b, at which the correct horizontal distance H must be read, is the perpendicular projection on the reading-line b of the middle point of the versed sine of the angle $2\,n$ to the radius (R + C) = D; second, that the reading-wire P^2 is so adjusted to the slide P^4 and the indexes are so placed on this slide that if the indexes are made to coincide with the same division on the reading-line b' as that at which the reading-line S or T is set on the reading-line K the wire will cut the reading-line b at a point which is the perpendicular projection on the reading-line b of the middle point of the versed sine of the angle $2\,n$; third, that the unit divisions of the vertical reading-lines S and T must be twice as long as those on the reading-lines b, b', and K.

First. In the diagram Fig. 5, K′ R = D, K′ F is also equal to D, and the angle R K′ F is equal to $2\,n$. The distance K′ N from K′ to the intersection of the perpendicular reading-line S with the line W is equal to D cos. $2\,n$, and therefore D — D cos. $2\,n$, or D (1 — cos. $2\,n$) is equal to N F, which is the versed sine of the angle $2\,n$ to radius D. Now

$$\frac{D}{2} + \frac{D}{2} \cos.\, 2\,n = D \cos.\, 2\,n + D\,\frac{(1 - \cos.\, 2\,n)}{2},$$

and since the first member of this equation is the expression for H, we can write

$$H = D \cos.\, 2\,n + D\,\frac{(1 - \cos.\, 2\,n)}{2}.$$

The second term of the second member of this equation is the correct expression for the versed sine N F for the angle $2\,n$ to radius D. Letting N F = V, the equation can be reduced to

$$H = D \cos.\, 2\,n + \frac{V}{2},$$

which proves that the correct horizontal distance must be estimated from the point K′ to the middle of the versed sine N F = V.

Second. On the point K′ as a center and with radius R + C = D, R being the number on the reading-line K to which the reading-line S is placed and C the distance from the point K′ to the zero-point of the reading-line K, describe the arc R F, intersecting the line W at F. The line N^2 N^3 on the base-piece L′ of the vertical device L, on which the eyehole P′ is located, is parallel to the reading-line b and at a distance from it equal to that between the reading-lines b and b'. Draw perpendiculars from the two extremities of the versed sine N F to the reading-line b', intersecting it at the points m and m', also the line N^2 N^3 at c and c'; also, from the middle point of the versed sine N F draw a perpendicular to the reading-line b, intersecting it at the point h. Now since the distances $c\,c'$ and $m\,m'$ are equal and also equal to the versed sine N F, and the lines N^2 N^3, b and b' are parallel, if a reading-wire be drawn from c to m' it will bisect the projection of the versed sine N F upon the reading-line b at the point h and indicate on the reading-line b the correct horizontal distance. If the end of the reading-wire at c be moved to the right and made to coincide with the eyehole P′ midway between the reading-lines S and T, and the end at m' be moved to the left the same distance to the point P^3, the wire will still pass through the point h and bisect the versed sine distance N F as before. Make the end of the wire fast at P^3 to the slide P^4 and draw the wire through the eyehole P′ and make it fast to the spring in the tube P. On the slide place an index P^5 to coincide with the number R′ on the reading-line b' the same as

that to which the reading-line S is placed on the reading-line K. Call the distance between the reading-lines S and T d, then the distance from P^3 to m' is $\frac{d}{2}$, because this was the distance moved to the left. The distance from R′ to m' is C. Therefore the distance from P^3, at which to make the wire fast to the slide, is $\frac{d}{2} - C$. Now move the vertical device L to the left until the reading-line T coincides with the same number R on the reading-line K′ to which S was set. Then the eyehole P′, with the wire, will have moved to the left the distance d to the point c^2, and the point P^3 must now be moved in the opposite direction or to the right the same distance d to the point c^3 in order to cause the reading-wire to pass through the point h. The distance from the position of P^3 at c^3 to the number R′, at which the index should be placed, is

$$d - \left(\frac{d}{2} - C\right) = d - \frac{d}{2} + C = \frac{d}{2} + C;$$

that is, the distance to the right of the fixed end of the wire at which to place the index for the reading-line S is equal to half the distance between the reading-lines S and T, minus the correction C, and the distance to the left at which to fix the index for the reading-line T is half the distance between S and T, plus the correction C.

It will be observed that for any given distance and angle of inclination the reduced horizontal distance should be the same for either reading-line S or T, so that the reading-wire ought to indicate the same horizontal distance on the reading-line b in either position of the vertical device L.

Third. The expression for the correct elevation to be read from the reading-lines S and T is

$$E = \frac{D}{2} \sin. 2n;$$

but we see from the diagram that the distance N R, expressed in units of D, is equal to D sin. $2n$—a result twice too large. If the units of distance on the reading-lines S and T are made twice as long as those on the reading-lines b, b', and K, the numerical expression for the elevations will always be correctly given.

It remains to be proved that the elevations of the observed point above an assumed base can be obtained at once from the apparatus.

The scales S and T can be adjusted so that any tenth division of the first unit division of either may be made to coincide with the line W. The belt-ribbons S′ and T′ can be turned until any desired number is brought opposite the first graduation mark on the scales

S or T, respectively. The numbers on the ribbon S′, which is used for angles of elevation, read up, and those on the ribbon T′, which is used for the angles of depression, read in the opposite direction. The scale S and belt-ribbon S′ and the scale T and belt-ribbon T′ can therefore be set so that the reading of the scales S and T, respectively, at the point formed by the intersection of the line W with the reading-line S or T will be the same as the elevation of the station occupied. It has already been shown that the distance from the line W to the point where the reading-line K cuts the reading-line S or T is the correct difference in elevation between the station occupied and the observed point.

As the numbers on the belt-ribbon S′ or T′ are consecutive, it is evident that for any given angle the reading on the scale S at the intersection with the line K will be equal to the elevation of the station occupied plus the difference of elevation, and the reading on the scale T at the intersection with the line K will be equal to the elevation of the station occupied minus the difference of elevation.

The operations of the apparatus will be explained by means of a practical example. Suppose the observed angle of elevation or depression to be eighteen degrees twenty-six minutes and the rod reading to indicate a distance of forty-five feet. Set the vernier K^2, Fig. 1, on the arc M so that the reading will be eighteen degrees twenty-six minutes. Then the real angle between the reading-line K and the line W will be thirty-six degrees fifty-two minutes or $2n$, as required. Suppose the elevation of the station occupied to be 1444.4 feet above base. Now to adjust the scale S for this elevation make the ".4" graduation of the first unit interval on scale S, reading up, coincide with the line W. Move the belt-ribbon S′ by means of the finger-wheel S^3 until the number "144." is opposite the first graduation-mark of scale S, as shown on Fig. 5, and the scale S is numbered for angles of elevation for this particular station.

The adjustment of the scale T for angles of depression is the same as that for scale S, only, as the numbering on the belt-ribbon T′ is in an opposite direction to that on the belt-ribbon S′, the .4 graduation of the lower unit interval of the scale T, reading down, would be placed on the line W. To number the scale, the finger-wheel T^3 would be turned until the number "144" coincided with the first unit graduation above the line W. Thus adjusted, both scales would indicate the same elevation of the line W when read in their respective directions. Move the vertical device L until the reading-line S coincides with the reading-line K at the

number "45," which is the observed distance, and the correct elevation of the observed point above the assumed base can be correctly read, which, as shown by Fig. 5, is 158.2. To obtain the horizontal distance, the slide L′ is moved until the index P^5, Fig. 5, coincides on the reading-line *b′* with the number "45," and the reading-wire will cut the reading-line *b* at *h*, indicating the reading 41.41, which is the correct horizontal distance.

If the angle is one of depression, the vertical device L is moved until the reading-line T coincides with the number "45" on the reading-line K, and the correct elevation of the point is read from scale T, which would be 130.6. (See Fig. 5.) To obtain the horizontal distance, the slide L′ is moved until the index P^6, Fig. 5, coincides on the reading-line *b′* with the number "45," and the reading-wire will cut the reading-line *b* at *h*, indicating the reading 41.41, the same as when scale S was used.

MONUMENTS.

Although the ordinates of all corners and angles are noted on the plans, it is necessary to have permanent points located at convenient intervals from which any desired line may be easily laid down. For this purpose it has been necessary to place on the average about two monuments to a 1000-foot section in the ground. These monuments are so placed that they bear a definite relation to one or more street lines. They have been placed in most cases upon an offset line usually four feet from a street line, although it has sometimes been found convenient to place them on the range of a street line. These monuments are set in concrete. Two styles have been used.

Those shown in Fig. 6 are wholly below the surface of the ground. Set in concrete for five feet of their length, the top being surrounded by a brick dome, on which is set an iron rim with a movable cover.

The style of setting shown in Fig. 7 consists of a stone eight inches square and five feet long, four feet of which is imbedded in cement, the tops being flush with the surface, and centered with a small drill hole.

The ordinates of each monument, together with its location, are given upon the plans.

From 1891 to July, 1895, this survey was carried on under the direction of the Board of Survey, composed of three members. By an act of the Legislature the work was transferred to the Board of Street Commissioners and the Board of Survey abolished. This act took effect July 1, 1895. Before the lines laid down upon any

territory can become valid, a public hearing upon the plans to be filed must be given, after two weeks' notice by advertisement in at least two daily papers. These notices to appear twice each week, the last notice to be given at least two days before such hearing. No plans shall be filed until sixty days have expired after the public hearing. When the plans are filed they shall bear the signatures of the Street Commissioners and the Mayor. When received by the City Engineer, his signature as custodian is affixed, together with the hour and date on which they came into his custody.

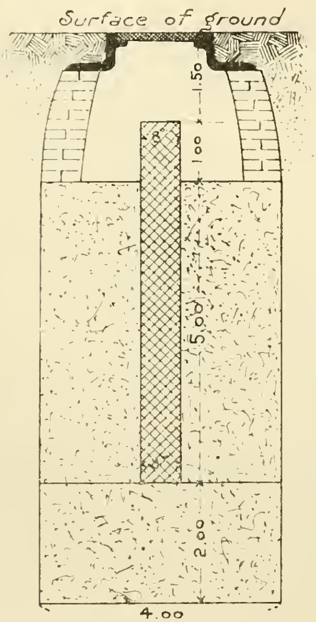


Fig. 6

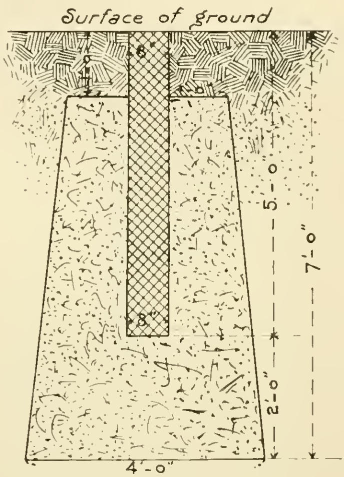


Fig. 7.

After filing, no plans shall be altered without a public hearing and procedure as though no plan had been filed.

When, in the opinion of the commission, public convenience requires the laying out of any streets shown on the plans, the board may proceed in the usual way and order the laying out and construction of such streets, and assess the total cost upon such land as lies within 125 feet of the street, provided the street does not exceed 50 feet in width.

Payment may be made at once or in ten annual instalments, with interest at $4\frac{1}{2}$ per cent., at the option of each owner.

When the street laid out is more than 50 feet in width there

shall be deducted so much of the expenses of laying out, locating anew, altering, or widening or constructing the highway, as said board, with the approval of the Mayor, shall determine that the public should assume and pay, and the remainder of said cost shall be the assessable cost of the work done under the order.

The order for construction includes all work to be done for the full completion of the street, including grading, surfacing and sidewalks, gas, water and sewer pipes, with provisions for house connections.

The gas, water and sewer pipes are not included in the assessable cost.

That real estate may not suffer for want of development during the progress of the work, the Board of Street Commissioners have the power to issue permits to owners of property to open new streets into public thoroughfares, if submitted plans, showing locations and grades, meet with its approval, these streets, later on, becoming a part of the new system.

The irresponsible method in vogue previous to 1891 is thus completely done away with.

The law of 1891 was radically different from any law which had ever been in operation in Massachusetts.

It had not been the custom in this State to condemn private land for streets which might not be built for years, for which no payment might be demanded.

Real estate dealers feared that their business would be at a standstill until the work of the board was completed; that no one would dare to buy or build until the plans were complete and the new lines known. These fears have not been realized. But there are questions which are still being asked which are of interest to every real estate owner:

Is a law constitutional which takes a right from the individual without allowing a claim for compensation therefor?

Does the filing of plans defining a future system of streets constitute an incumbrance upon property?

The city claims that both of these questions were virtually answered by the Supreme Court in 1896, when they gave their decision in the case of Daniell *vs.* Shaw.

This was a case where Daniell conveyed a parcel of land to Shaw which he described as free from all incumbrances. Upon examination Shaw found that the plans filed contemplated a widening of the street, for which a strip of the proposed purchase would be required, and thereupon refused to consummate the agreement, whereupon Daniell brought suit against Shaw to compel him to

take the land, claiming that the law under which the line was laid down was unconstitutional.

The city, although not a direct party to the action, was allowed to file a brief, claiming that in laying down the line it exercised its rights of restriction under what may be termed its police powers, and that this restriction was of the same nature as those in the building laws, and as to the brick limits, the height of structures and the uses to which buildings shall be put.

The city law department held from the very first, and does now, that an owner can recover for damages to a building placed within the street lines as laid out under this act, and could use his land as before, except that he could not recover for grade damages when the proper grades had been determined and established and he had disregarded them.

The plaintiff conceded that the title was not good if the law was constitutional. The opinion of the court was very brief, viz— "The defendant ought not to be compelled to accept such a title."

In the report of the case (166 Massachusetts, page 582) the line referred to is stated to be an incumbrance within the meaning of a written agreement.

While the court did not pass directly upon the constitutionality of the act, the inference may be drawn that as the plaintiff relied upon the constitutionality to make his title good, and the court decided that the defendant was not obliged to take such a title, that the restriction was legally put upon the land; and the court did not declare the act constitutional in so many words, because it was so clearly implied by the decision dismissing the plaintiff's bill.

While it may be argued that a man cannot be compelled to buy a lawsuit, and if there was any doubt about the title, he should not be compelled to receive it, with a risk of a contest later; the unconstitutionality of the act was the very point on which the plaintiff relied for an order from the court declaring his title good.

Although the proposed lines constitute restrictions upon property, the incumbrance is a decided public benefit, and, in most cases, a private one as well.

It is a great advantage to the owner to know, when he constructs a street through his estate, that his neighbors will develop their property upon the same lines, while pursuing the old method he had no surety that his street would ever lead to another thoroughfare or be anything but a dead end place.

These lines may leave small or irregular-shaped pieces of ownership, but with a comprehensive system as a future possibility new estate lines are likely to be made by purchase or exchange

before there becomes a demand for the construction of the new avenues and the subdivision into smaller city lots.

Purchasers of homes have also the means of forecasting the character of their vicinage, and will be more ready to locate in the remote and less settled sections than formerly.

Manufactories are more likely to seek locations where the street development promises to afford certain conveniences.

It may safely be asserted that the benefits to accrue from a wise and far-seeing policy in laying out this street system are so numerous that the disadvantages will become insignificant, and eventually will disappear altogether.

THE PORTLAND CEMENT INDUSTRY OF THE WORLD.

By Bernard L. Green, Member of the Civil Engineers' Club of Cleveland.

[Read before the Club, May 10, 1898.*]

The technical literature on the subject of cement has grown to such enormous proportions in recent years that the writer feels no little hesitation in venturing an addition. But, while some of the matter here presented may be familiar to many, much of it is the result of personal investigation and study, and it is hoped that the paper as a whole may contain a morsel or two of valuable matter for all.

It is interesting to note that probably the first man to determine the great principle of hydraulic cements was Smeaton, and in connection with the foundation of the very lighthouse that has made his name famous the world over. His experiments in the search for materials for a satisfactory hydraulic lime taught him that the acquisition of hardness under water does not depend upon the hardness of the stone from which the lime is made (a theory that had previously been generally believed from the time of Vitruvius), but in burning and falling down to a powder of a buff-colored tinge, and in containing a considerable quantity of clay. These experiments, though made in 1756, were not published until 1791 in his "Narrative of the Building, etc., of the Eddystone Lighthouse." In this same year Dr. Parker's accidental discovery of the hydraulic properties of the septaria on the Island of Sheppey started an immense business in the manufacture of natural cements. So great did the demand for them become that grave fears were entertained of the early exhaustion of supply, and consequently the search was eager for a process of making cement artificially. Prominent in the study of the problem were Pasley, in England, and Vicat, in France, and the latter in 1818 published a method for making hydraulic lime from clay and lime. In 1822 Frost took out a patent in England for the making of hydraulic lime by the method of Vicat, and the plant he established at Swanscombe, on the Thames, has developed into that of Messrs. White Bros.

Among the many searching for an artificial method of cement manufacture was Joseph Aspdin, a bricklayer of Leeds, who, in 1824, having discovered a manner of combining certain ingredients to form a cement fairly hydraulic, adopted the custom of others

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who sold various kinds of cements to give them distinctive names or brands. He chose to call his product "Portland Cement" in consequence of its fancied resemblance in point of color and texture to the oölitic limestone of the Island of Portland, well known and in great favor in England as a building stone.

Aspdin's specification, No. 5022, is dated October 21, 1824, and is for "An Improvement in the Modes of Producing an Artificial Stone," which invention he thus describes: "My method of making a cement or artificial stone for stuccoing buildings, water works, cisterns, or any other purpose to which it may be applicable (and which I call Portland cement) is as follows: I take a specific quantity of limestone such as that generally used for making or repairing roads, after it is reduced to a puddle or powder, or the limestone, as the case may be, to be calcined. I then take a specific quantity of argillaceous earth or clay, and mix them with water to a state approaching impalpability, either by manual labor or machinery. After this proceeding I put the above mixture into a slip pan for evaporation, either by the heat of the sun or by submitting it to the action of fire or steam conveyed in flues or pipes under or near the pan, until the water is entirely evaporated. Then I break the said mixture into suitable lumps, and calcine them in a furnace similar to a lime kiln till the carbonic acid is entirely expelled. The mixture so calcined is to be ground, beat, or rolled to a fine powder, and is then in a fit state for making cement or artificial stone. This powder is to be mixed with a sufficient quantity of water to bring it into the consistency of mortar, and thus applied to the purposes wanted."

Portland cement is produced from the intimate mixture of lime and clay, burned to a point just short of vitrifaction and ground to a fine powder. It is thus essentially an artificial product and clearly distinguishable from the natural cements. It can be made from any materials having the various necessary ingredients in the proper proportions, and these proportions may vary between narrow limits, depending somewhat on the method of manufacture. Scientists have now proved almost conclusively just what chemical combinations and reactions take place upon the calcining of the raw materials, and also when the resulting cement is mixed with water and allowed to set. So there is nothing in the fundamental principles of Portland cement making in which one manufacturer can claim superiority over his rivals; no secret processes, no patented methods; and his only chances to win the race of keen competition lie in natural advantages of raw material, location of plant, cost of fuel, choice of mechanical appliances and price of labor.

These are the main points of comparison between different countries and different factories, and naturally form the chief objects of interest in such a comparative study.

ENGLAND.

Proceeding now to the consideration of the past and present state of the industry in each of the cement-producing countries in its turn, England will naturally have first place.

The period between 1824 and 1850 forms the dark ages of the industry, and little is known of its history during that time. At the latter date there were but four factories making Portland cement, and the process was still crude and the product of uneven and unreliable quality. Indeed, the new industry was so little known that Pasley, who for long years continued researches similar to those of Vicat, is said never to have heard, before the Exposition of 1851, of the substitute for Roman cements, although he lived at Chatham, near the Portland works of Aspdin's son. Competition and tests made by interested parties, soon increased the general confidence in the material, other factories sprang into existence and the product increased rapidly and steadily. In 1874 we find an estimate of the exports from England for that year placed at 1,350,000 barrels, and exports increased steadily to 3,500,000 barrels in 1890.

The Portland cement factories of England may be divided into two general classes, based on the materials used. The first is closely confined to the lower Thames and the Medway, an adjoining estuary, and the materials used are chalk, found in abundance in the rolling country bordering these streams, and an unctuous blue clay, commonly called Gault clay, largely obtained from the beds of the streams by dredging. Fully 80 per cent. of all the English Portlands are produced from this district, and practically all the exports to America are from them. The chalk formation is quite uniform at all points. It begins but a short distance below the surface with a layer of almost pure calcium carbonate containing large quantities of flints. Just below comes a smoother, darker-colored chalk containing a considerable proportion of clay. A third layer contains still more clay, but on account of its depth and tendency to impurity it is not often used in cement making. Below all occurs the Gault clay, but, as stated above, this material is generally obtained by the cheaper process of dredging the streams. Both the first two layers of chalk are used, some makers preferring one and some the other. The following group of

analyses of the materials, the raw mix and the resulting cement, is fairly representative of the cements of this district:

GREY CHALK.		DRIED CLAY.	
Sand and clay,	4.85	Sand,	28.42
Combined silica,	0.78	Combined silica,	30.32
Alumina and oxide of iron,	0.53	Alumina,	15.49
Lime ($CaCO_3$),	73.84	Oxide of iron,	7.74
Magnesia ($MgCO_3$),	0.66	Lime (CaO),	2.04
Alkalies, organic matter and loss,	1.95	Magnesia (MgO),	1.96
Moisture,	17.39	Sulphuric acid,	1.96
		Water and loss,	12.07

DRIED SLURRY.		CEMENT.	
Sand and clay,	12.68	Silica,	20.68
Soluble silica,	3.23	Alumina,	9.50
Alumina,	2.51	Oxide of iron,	4.06
Oxide of iron,	0.40	Lime,	61.96
Lime ($CaCO_3$),	75.32	Magnesia,	1.07
Lime (CaO),	1.31	Sulphuric acid,	1.04
Magnesia,	0.41	Water and carbonic acid,	0.46
Water and loss,	4.14	Insoluble residue,	0.82
		Alkalies and loss,	0.41

The old original process, or "back" process, is still largely in use in the Thames district, although many manufacturers are changing to cheaper and more rapid methods. The former method seems to produce the best cement still, and is much favored by many engineers in England; but the greater time consumed and the higher cost of handling are rapidly making its use prohibitory in competition. It consists of mixing and grinding the chalk and clay together in sludge mills with 120 to 140 per cent. of water and floating off the finely divided particles over weirs to settling backs. When a back is filled the mixture is allowed to settle and the clear water is drawn off over weirs as far as possible, the sun then drying the mass to the consistency of warm butter. (This method of drying often takes a month.) It is then spread on drying floors where, either by separate coke fires or by waste heat from the kilns, it is evaporated to dryness.

The new method, coming more and more into use and known as the semi-wet or Goreham process, consists of mixing with only 30 to 40 per cent. of water in similar sludge mills, followed by grinding to a creamy texture between mill stones. The mixture is then pumped directly to drying floors connected with the kilns, where the waste heat dries the mass in about 18 to 20 hours. It is evident that the latter process must be much the cheaper, saving about a month of time between raw materials and finished cement, besides

the great area requiréd for the backs; but the most complete mechanical grinding together of the raw materials seems to be inferior in results to the old process of mixing by water.

The second general division of English factories before mentioned, and comprising all those plants not of the Medway-Thames district, may be represented by the works upon the river Tyne, although there are several factories in other parts of England. The materials are totally different, being a hard, compact, shaly limestone, called blue lias, rich in clay. The methods consequently differ considerably in the preparation of the raw materials, requiring either dry grinding or calcination of the lime rock before finally mixing with the clay. These cements are not generally so highly favored among engineers as those of the Medway-Thames district, being liable to lack of uniformity, owing to the great variability in the lime rock, and frequent trouble with blowing or swelling. The writer was shown a briquette of such cement, having an original length of 7½ inches, which, atter the boiling test, had swelled to 8 inches. This, of course, was an extreme case.

The Johnson kiln is quite generally used in England, it having now almost entirely replaced the older and simpler kilns built after the pattern of the lime kiln. The Johnson kiln is of similar shape, but includes large drying floors behind the shaft, below and above which the hot gases pass to the chimney and thus dry the next charge of slurry placed thereon. Gas coke is quite generally used, and it requires from 700 to 900 pounds of coke to dry and burn a ton of clinker, costing about $1.00 per ton of clinker; or about 1200 to 1400 pounds of fuel to produce one ton of finished cement, including power for mixing slurry and grinding clinker.

Although many forms of grinders have been tried, the preference among manufacturers seems to be generally for the ordinary French burr millstones. Notwithstanding the greater power required, the product is said to be found so much better and more uniform as to pay. The power required to grind by three common methods is as follows:

Millstones, 30 to 32 H. P. hours per ton.

Ball Mills, 16 to 18 H. P. hours per ton.

Edge Runner Mills, 12 to 14 H. P. hours per ton.

All English cements are carefully inspected before use, to see that they are "cool," and if there is the slightest tendency to failure under tests for constancy of volume, they are spread out on warehouse floors to aërate or be "purged" before they may be used. This is a point which should be emphasized. The danger in using recently ground cement is not generally recognized in this country

and many consumers still specify that their Portland cement shall be "freshly ground." The danger is two-fold, since a highly limed cement is much more likely to blow when fresh than after it has somewhat seasoned, and no cement, whether highly limed or not, should be used until the heat produced in grinding has had time to subside. While the English cements seem to require somewhat more attention in this direction than those of other countries, still if this point were more carefully watched in the United States better results would be obtained, and many American cements, which some engineers now believe somewhat treacherous on this score, would be accepted with more alacrity upon works.

It is only very recently that the English manufacturers have begun to take steps toward the improvement of quality of their product. In the past they have been satisfied with the same methods and the same products obtained for years, and English consumers have not asked for any improvement. They have been satisfied with low tensile strength, light burning and coarse grinding. In fact, up to within five years a residue of 20 per cent. on a 2500 mesh sieve was not considered objectionable, and on the Manchester Ship Canal, where large quantities of cement were used, the specifications required not over 10 per cent. residue on a 2000 mesh sieve, and a minimum tensile stress, at 7 days, of only 310 pounds per square inch on a $1\frac{1}{2}$ x $1\frac{1}{2}$-inch section. But lately more care is taken in the little details that mean so much in close competition. The best English Portlands to-day stand very well with other standard brands of the world, and the English product is steadily improving, though among some of the manufacturers there is still room for further progress.

In 1895 the estimated production in England was 8,300,000 barrels per annum, or about 26 per cent. of the total European production. Its cost in the open market during the past year was about $1.40 per barrel, though on large contracts it was obtained for $1.25.

The following comparative table of actual costs per ton of finished cement may be interesting. No. I is said to give the actual cost from the books of a firm in the Medway-Thames district, and No. II an analysis of the costs in the Tyne district. As will be seen, though cost of fuel is considerably less, cost of materials is higher. In II., under the head of Depreciation, is included an item of bad debts that helps to swell the total, and the office expenses and cost of management are considerably higher. It has been authoritatively stated that in a thoroughly well-regulated plant in the Medway-Thames district cement could be produced at a total cost of only $4.08 per ton:

	Cost per ton of finished cement.	
	I.	II.
Raw material	$ .786	$ .911
Fuel	2.780	1.341
Wages	1.544	1.727
Rates, Taxes and Office charges	.176	.518
Repairs (including material and wages)	.419	.648
Stores (oil, firebrick, etc.)	.277	.263
Insurance	.019	.016
Depreciation of plant and Interest	.120	.634
Total,	$6.121	$6.058

The largest manufacturers are Messrs. Hilton, Anderson, Brooks & Co., at Grays, Essex, being a combination of the firms of Hilton, Anderson & Co., and Brooks, Shoobridge & Co. This firm turns out about 800,000 barrels annually. Among other firms producing large quantities may be mentioned the Francis Works, at Cliffe, in Kent; White Bros., the Burham Co., and Robins & Co.

For the past two years there has been considerable agitation over the adulteration of cements by some makers. A favorite adulterant is a hard limestone known as Kentish Rag, containing about 92 per cent. pure calcium carbonate, and some of the makers using it claimed it to be beneficial. After exhaustive studies by experts, however, no beneficial results have been found, and steps have been taken among manufacturers for their protection against those who practice the adulteration.

FRANCE.

There is considerable rivalry between the English and French for the credit of the discovery of Portland cement, and not without reason, for Vicat, who made the subject a life study up to the time of his death in 1861, published the description of a method for making an artificial hydraulic material which must have been quite as good as Aspdin's; but he called it "hydraulic lime," and thus seems to have been ruled out. But it was not for many years that the manufacture of this material was undertaken on any large commercial scale. The works of the Gate of France were started in 1842, the result of a discovery, near Grenoble, of a natural cement rock. These works later began the use of an artificial mixture to increase the time of set. The sons of Vicat established works in 1857; and about 1859 Demarle, who had been making natural cement near Boulogne for some fourteen years, was successful in copying the English cements, was the first of several manufacturers to impress French engineers with the excellent qualities of their domestic product. About 1870 French cements began to

steadily displace English brands in the French market until, in 1885, when the manufacture came under the direction of the Government, foreign brands were almost entirely displaced.

The Government control over the industry mentioned above is worthy of note. It is a law that Government inspectors shall have access to works at any time, and have power to order corrections in the mixtures, or changes in the details of manufacture, if they see fit. The manufacturers thus have less chance for competition and the exercise of individual methods, and the system might be expected to militate against healthy progress in the quality of product. Such does not seem to be the case, however, if one may judge from published reports of results of tests upon several of the most largely used brands.

The materials mostly in use are marl and clay, or chalk and clay. The methods of manufacture are much the same as those in England, but more care is taken as to regularity of mixture, burning and grinding.

Although the total output in 1880 was only about 750,000 barrels, it is at present nearly 3,000,000 barrels. The principal factories are at Boulogne sur Mer, the entire plant of the association forming probably the largest company in the world, with the enormous annual output of 2,200,000 barrels, 73 per cent. of the entire production in France. In the department of the Isère there are a few important works producing 9 per cent. of the total French output. Other factories, in the departments of the Yonne, the mouth of the Rhone, the Seine and Oise and the Lower Charente, make up the remaining 18 per cent. Concerning price, there are two qualities quoted upon: the first being made from clinker carefully selected by the inspectors for its density and perfect calcination, and the second that ground from the remaining clinker as it comes from the kilns, first, however, having picked out any seriously underburnt material. The first quality varies in price from $1.00 to $1.25 per barrel at the works, and the second quality between 65 cents and $1.00.

France exports considerable quantities of cement every year, the greater amount going to Switzerland and the countries bordering on the Mediterranean. The total quantities exported have not varied much since 1890, being in 1891 about 1,065,000 barrels, and in 1894 1,087,000 barrels. In 1896 it was 1,139,000 barrels, or 39 per cent. of the total amount manufactured. Imports have been very small, the greatest amount coming from Belgium and used as a cheap grade, though a certain quantity is also imported from England. The quantities imported, moreover, have steadily decreased from 153,000 barrels in 1891 to 83,000 barrels in 1896.

GERMANY.

The first step toward the manufacture of Portland cement in Germany was taken in 1852, when Dr. Hermann Bleibtreu, of Bonn, erected an experimental station at Züllchow, near Stettin, on the Oder. The experiments led in 1855 to the establishment of a Portland cement plant in that place, the product of which so rapidly found favor that an annual production of 30,000 barrels was easily disposed of. Other factories soon began operations in various parts of the country: the Mannheimer in 1861 and those of Lüneburg, Amöneburg, etc., in rapid succession. The methods were at first directly copied from the English, whose product had previously held the highest reputation in Germany; but it was soon found that the various classes of materials used in different localities would not at all adapt themselves to these methods. German patience and careful study prevailed, however; new and more appropriate methods were devised by the experts employed by the various makers; and the result has been most gratifying. Not only has the quality become equal to that of English cements, but it has often considerably surpassed it. By 1877, at which date there were some 30 factories, with an aggregate annual output of 2,500,000 barrels, the peculiarities of the various materials in use in different localities were pretty well understood and the methods perfected.

It was in this year (1877) that the "Association of German Portland Cement Manufacturers," although not known by that name until some ten years later, was founded; and this organization of makers, for their mutual protection and for combined research and experiment, had a very strong influence in bringing the industry in Germany to the position it holds to-day as the best developed in the world.

Three general classes or districts among German factories, based upon the character of the raw materials, are quite distinct. First, those of North Germany, bordering the North and Baltic Seas, where the materials are mostly chalk and clay, very much like the materials of the Thames and Medway districts of England. The wet or back process is quite commonly found here. It was copied from the English method and, proving adequate, was never changed. Among the principal factories in this district may be named the Alsen, Lägerdorfer and Hemmoor, on the Elbe, having a combined annual output of some 2,000,000 barrels, of which the Alsen works produce about one-half; and the six works at Stettin, on the Oder, having a total annual production of 1,000,000 barrels.

The second division comprises those factories using marl and clay as raw materials. These lie generally in the south central part

of the empire and include such works as those at Hanover, Heyer Bros. at Lüneburg, and the Germania works at Misburg. In this division appears the greatest difference in manner of preparation of materials. At Hanover dry grinding is used, the raw materials being carefully dried at the outset. It will be interesting to note that the Cummer Dryer, built in this city, is used at the Hanover works for this purpose. Only enough water to mould bricks for burning (5 to 7 per cent.) is added after grinding. The marl deposit at Hanover is remarkable for its depth of over 40 feet, underlaid by the clay. At Lüneburg, although the same materials are used, the wet process is in use.

The third division covers those factories obtaining their lime from limestone rock of greater or less hardness. Three representative factories of this class are those of Messrs. Dyckerhoff & Sons, at Amöneburg-on-the-Rhine, and the Mannheimer works at Mannheim and Wiesenau. The Amöneburg and Mannheim works are among the oldest in the empire, the latter antedating the former by a few years, and are of interest as being probably the first to discard the English methods as not adapted to their raw materials, and successfully adopt methods resulting from careful study of the peculiar needs and conditions of the respective materials.

While the wet or back process is in use in some of the mills of the second division, the semi-wet and absolutely dry processes are most frequently found. Among the mills using limestone dry processes are almost altogether used, though some grind the clay wet and mix the wet clay with the dry lime to form a paste of a consistency to work well in the brick machines later on. The Dyckerhoffs employ an interesting combination of the dry and wet processes. Two quite different materials furnish the lime ingredients required, one a rich limestone rock, quite hard, and the other an argillaceous chalky lime, containing nearly enough clay in its natural state. The clay is a bluish-brown, fat clay, obtained from the low-lying river lands near Frankfurt. It is dried in special furnaces before mixing. By one process the hard limestone and the clay, in proper proportion, are run through Blake crushers and then ground to powder on French burr stones. The clayey chalk is corrected with clay to the proper proportions and put through a wash mill with an excess of water. The resulting creamy mixture is ground between burr stones and then pumped to settling tanks like the old English "backs." When, by evaporation and settlement, the material has become thick enough to be handled with scoops, it is taken to a mixing mill, where enough of the dry

ground mixture is added to make a stiff dough suitable for the brick machines quite generally used in Germany for preparing the slurry for final drying and burning.

As to the other steps in the process of manufacture, it is evident that the Germans have studied the matter carefully and solved the problems in each case to suit the conditions. Thus, for burning, while the old intermittent Johnson kilns are found in some plants, the more economical and continuous Dietsch and Hoffman kilns are very much used. And again, while the English in general find the French burr millstones the most satisfactory, many German factories are using various kinds of ball mills, tube mills and the Griffin mills.

The Germans are probably the most advanced of any nation in the realization of the great variety of uses to which cement lends itself. While the English use it for strictly structural work in concrete foundations, breakwater works, etc., and the French have adopted it at times for more ornamental work, Germany constantly uses it in the most diverse ways. One finds it forming a wearing surface for pavements, the cornices and other ornamental work of buildings,—sometimes for the entire walls,—for curbing, sidewalks, heavy balustrades and even for statuary. Perhaps some will, in this connection, recall the beauty of the colossal statue of Columbus at the Chicago Exposition in 1893. It stood at the entrance to Machinery Hall and was a monolith of the Alsen Portland cement.

There are at the present time some sixty different factories of Portland cement in Germany, with a total annual output of 13,500,000 barrels, over 40 per cent. of the entire production in Europe. The exports now amount to about 3,000,000 barrels each year, of which over one-third comes to the United States.

Prices of cement in Germany are very low. The Stettin factories are said to be manufacturing at a net cost of about 77 cents per barrel, not including cost of barrel. The average price in the open market appears to be about $1.25 per barrel. A pool of the manufacturers of Germany considerably limits the brands of cement that may be offered for use in any one locality. The question to German engineers as to which brand of cement they consider the best is always answered, "We are allowed no preference; such a brand (naming, perhaps, the factory nearest to hand) is the only one we ever use." Indeed, competition is so fierce that some such protection seems almost necessary; and since the careful Government supervision and the organization of the manufacturers themselves keep the quality to a high standard, and the price within bounds, this pooling for sales seems harmless.

BELGIUM.

The Portland cement industry is said to have been carried into Belgium from England by a son-in-law of Aspdin, although a recent Consular report states that it was first carried on in 1872 by Messrs. Duffossez & Henry, of Cronfestu. Its history in that country is, however, obscure and probably of little interest. Belgium is pre-eminently the home of the "Natural Portland Cement." The makers of this material and of the artificial or true Portland have each their organizations, but the two organizations have nothing in common.

The natural Portlands were first made in 1882, and the principal works at present are at Tournai, Chercg, Calonne, Antoing, Vaulx, Gaurany and Ghent. A syndicate has been formed of nearly all these factories, under the name of the "Mutualité Commerciale des Ciments Belges," with headquarters at Tournai. This combine forms the syndicate selling the "hammer brands," and its output amounts to about 1,200,000 barrels annually. The materials used for these natural Portlands are quite generally an argillaceous limestone of a very fine, close grain and of a peculiar pasty appearance. Its average analysis is as follows:

Silicic acid	15.75
Oxide of iron	1.00
Alumina	3.95
Lime	43.10
Magnesia	0.49
Sulphuric acid	0.50
Loss in firing	35.21

This rock is frequently analyzed and corrected or "dosed" with clay to keep the product of the proper quality, but the greatest care and frequency of analyses could hardly be expected to produce cement of so uniform quality as that made from a truly artificial mixture, unless the natural rock were particularly excellent for uniformity and purity. Beyond this difference in the raw materials, the methods of manufacture do not differ materially from those of makers of artificial Portland.

The artificial Portland is now made by several firms, among which may be mentioned those of Dumon & Co., Tournai; Duffossez & Henry, Cronfestu; Société Anonym de Niel on Ruppel, and North's Works at Beerse. The last two are probably the most extensive works, and the last particularly is a very interesting plant, having been but recently designed and built with special regard to the best and most economical machinery and methods. The wet

or "back" process is used, the backs being equipped with the Cummer Dryer, for use in winter. The Dietsch kilns are used and all the best labor-saving mechanical devices employed throughout the mill to secure uniformity of product and economy of labor. This plant turns out about 400,000 barrels per annum and ships about one-fourth of its output to the United States.

The total output of Portland cement, both natural and artificial, is estimated to be about 2,250,000 barrels per annum, and of this amount probably about two-thirds is exported to Holland, France, Switzerland, America, and even to England and Germany to some extent. Its cost in the Belgian market varies between \$1.00 and \$1.25 per barrel for the artificial Portlands, and from 65 to 70 cents per barrel for the natural Portlands.

While most, if not all, of the artificial Portlands of Belgium are of good quality and will rank with those of other countries, Belgian cement in general holds but a second place in the estimation of engineers. The large quantities exported to other countries find a market chiefly on account of low price, and they are frequently excluded when work requiring a high class of cement is to be undertaken. Thus Holland, with no cement factories of its own, imports large quantities from Germany, England and Belgium; but the engineers generally rank the latter cements as good for use only under conditions similar to those in our own country under which our engineers use the cheaper but less uniform natural cements. There is in Holland a difference in price of about 25 cents per barrel between Belgian and German Portlands, the better quality of the former costing about \$1.23 per barrel, while the latter sells for \$1.50.

AUSTRIA-HUNGARY.

Statistics from Austria-Hungary are somewhat confounded. In Austria there are some eleven factories forming an association similar to that of Germany, and the quality of their products is good. The aggregate annual output from these is about 1,000,000 barrels. Information concerning other factories, not represented in the association, has not been obtained. Austria ships a considerable amount of cement to Hungary and to other countries and provinces in Eastern Europe. The Association of Manufacturers was organized about the same time as that of Germany, and the researches and steps taken for the improvement of the product have been along much the same lines.

Hungary has about a dozen factories, but their annual output is not published. Small quantities are imported from Germany, as

well as some 100,000 barrels annually from Austria. Domestic cement costs about $1.30 per barrel and imported about $2.00.

RUSSIA.

Portland cement was made as early as 1857 in Russia, but did not receive careful attention nor attain reputation till about 1888, and up to that time large quantities were imported from Germany. By 1890, however, there were eight factories in existence, producing 900,000 barrels per year, and the German imports dwindled to very low figures. At the present time there are fourteen factories and the annual output is estimated at over 2,000,000 barrels, practically all consumed within the country.

SCANDINAVIA.

The Scandinavian states have a few very good Portland factories. In Denmark the largest and best equipped plant is at Aalbourg, on an arm of the sea running up into the Province of Jutland. The materials used are chalk and clay. Modern methods prevail throughout, a combination of the wet and dry processes is used, the burning is in continuous shaft kilns, and the grinding is done by ball mills followed by the use of tube mills for pulverization. There are in all five or six manufactories in Denmark, with an aggregate annual output of about 400,000 barrels, of which the Aalbourg works turns out about 250,000.

In Sweden probably the largest and best known works are those of the Skanska Company at Malmo. This plant was established in 1872, and its present annual output from two plants is about 225,000 barrels. Four other companies, including a solitary one recently built in Norway, have an aggregate output of 275,000 barrels, making a total, for Sweden and Norway, of 500,000 barrels. About 100,000 barrels of this are exported to Denmark, Russia and America. English and Belgium brands are imported in small quantities, but the home product is almost exclusively used. The price of cements in the Swedish market runs from $2.15 to $2.30 per barrel, rather a high rate compared with those in other European countries.

SWITZERLAND.

Switzerland has a few factories, the one at Aarau enjoying a certain reputation, but the quantities manufactured are insignificant. Considerable quantities are imported from Germany and Belgium.

ITALY.

In Italy there are three or four firms operating plants with a total annual product of about 800,000 barrels. The principal works are at Casale, in the Province of Monferrato. A new factory has recently been started at Civitavecchia, near Rome. These cements may nearly all be classed as natural Portlands, the process of manufacture being much like that in Belgium, already described. Italy imports about 700,000 barrels of cement annually, or about one-half of the quantity consumed, since there is very little exported. Most of the imported cement comes from France. The price varies from $1.75 to $2.00 per barrel, according to quality, there being two qualities much as noted in France. Contrary to the general belief, Italy is now using more cement than Pozzuolana. The latter material, so noted as an Italian cement for years, has yielded first place to Portland cement on important works in that country except in the Roman and Neapolitan districts.

SPAIN.

Spain has no Portland cement factories, natural cement alone being made, but considerable quantities of this are manufactured. Portland cement is imported largely from France, though English brands are used to a considerable extent. The imported Portlands cost from $1.65 to $1.80 per barrel.

OTHER FOREIGN COUNTRIES.

Portland cement works in other parts of the world are not of great importance. Their output is small, and generally the plants have been erected simply to meet demands in some locality on some piece of work where there are proper materials in convenient position. There are works in India, notably at Ghooting, where lime and calcite are used, and at Madras, where shell lime and clay form the ingredients. In New Zealand there is a well-organized plant at Mahmangi, north of Auckland. Portland cement is also made at Tongshan, in China, from limestone, fire clay, marl and a rough china clay. The wet process is used exclusively, and the plant has modern equipment. Its capacity is said to be about 100,000 barrels per annum. The product is used wholly in Government works.

The industry is developing steadily in Canada, and as the demand is rapidly increasing and good materials are said to be plentiful, it may be expected that still greater growth will ensue. The output in two years has been increased over 150 per cent. The Canadian Pacific Railway's works at Vancouver, B. C., built about

1890, are worthy of note. A limestone rock is used, being ground dry and then mixed with just sufficient water to be handled in brick machines. The Hoffman kiln is used and slack is the fuel instead of coke. It is claimed that by restricting the amount of water, 300 pounds of slack are made to suffice for burning a ton of cement, against 700 pounds of coke by the wet process.

Works are to be found in South America at Parahaybo del Norte and in many other places, but they are of little consequence in relation to the great industry as it exists among the great European and American nations.

UNITED STATES.

In our own country Portland cement was imported from England for several years before its manufacture at home was begun. The United States Government was probably the first to use it in large quantities, upon harbor and coast defense works about the time of the Civil War. The amounts imported for other purposes were small and the price was from $7.00 to $9.00 per barrel. Attention was rapidly drawn to the value of the material, and imports steadily increased. By 1875 the price had decreased to $3.50 and $4.00 per barrel, and in 1877 58,450 barrels were imported into New York.

In 1875 Mr. D. O. Saylor, after three years of experiment and study, placed upon the market a very good American Portland, and his success started many others in the industry. Some were doomed to failure, but the number of successful manufacturers steadily increased, and in 1890 there were 16 factories, making 335,500 barrels, or 14 per cent. of the total amount consumed. At present there are 30 factories, producing 2,304,000 barrels, and new plants are rapidly springing into existence. A more detailed history of the establishment of various factories may be found in a paper by Mr. Robt. W. Lesley, published in the Journal of the Association of Engineering Societies for November, 1895.

About 88 per cent. of the Portlands made in this country come from New York, New Jersey, Pennsylvania and Ohio, the other 12 per cent. being distributed between Texas, Colorado, Dakota, California, Oregon, Utah and Michigan. The materials available have not the natural advantages of those in England, but resemble more nearly the materials in Southern and Central Germany. The various plants all use one of two classes of materials: first, a more or less argillaceous limestone rock, which is treated with clay to form the proper proportions; and, second, a marl artificially mixed with clay. The only exception, to the writer's knowledge, is the

works of the Western Cement Co., at Yankton, S. D., where chalk is found, and where methods of the Medway-Thames district of England are available. Under the first head may be classed the mills of Western Pennsylvania and Southern Ohio, while the plants of New York and Northern Ohio are representative of the second class. Statistics show that last year one-third of all the factories, producing 23 per cent. of the total output of the country, used marl, the remainder using limestone.

Cost of labor is another disadvantage against which American manufacturers must contend. The cost of cement manufacture is about 87 per cent. labor, divided as follows:

Quarrying	40 per cent.
Burning	6 " "
Grinding	6 " "
Moving, etc	5 " "
Packing	3 " "
Coal and coke, staves and heading	27 " "
Total	87 per cent.

The following table shows how great a difference there is between the cost of labor here and in the European countries. It is only by the use of machinery best adapted to the purpose and by profiting by all the advantages of location, thus saving time and employing as little labor as possible, that the American has brought his product to its present perfection and his price to the point of sharp and successful competition with the foreign cements that have enjoyed so great demand in the past.

	Comparative Cost of Labor per Day.				
	England.	France.	Germany.	Belgium.	United States.
Quarrymen,					$1.50 to $2.00
Miners,	$0.52	$ 0.87	$0.52	$0.60	
Millers,	1.00	0.48–0.87	0.65	0.88½	2.00 to 2.50
Women Millers,		0.20–0.39			
Millwrights,	1.16	1.12½	0.70	0.83½	2.50 to 3.00
Laborers,	0.78	0.76	0.60	0.66	1.30 to 1.50
Women Laborers,		0.38½	0.24	0.57	
Engineers,	1.10	0.97	0.73	1.03	2.00 to 2.50
Coopers,	1.13	0.93	0.66	0.86	1.50 to 2.00

The semi-wet method is most commonly used in preparing the materials for the kiln, various devices for wet grinding being in use in different mills. The dry grinding is also frequently employed. There are one or two plants making a natural Portland, somewhat after the Belgian methods, but so far as the writer is aware in every

case the materials run more uniformly and the results are much better.

Both the continuous and intermittent forms of kilns are in use, and various forms of each are met with. The rotary kiln is largely used. Though this machine was first devised in England, it has been so successfully developed in this country that it may almost be called an American invention. It never succeeded very well in Europe, and its use here is viewed with a little surprise by European manufacturers. It is true the process is not adapted to all classes of materials, and cylinders have met with failure in some mills. But where the raw materials will permit its use, it does very good work and proves a very economical machine. At present about 48 per cent. of the total output of the United States is burned in rotary kilns. Petroleum fuel is used in them, while gas coke is the ordinary fuel in other forms of kilns.

Perhaps the best method of showing concisely the comparative progress of the Portland cement industry in the principal countries may be derived from the evidences of their comparative reputations in this country, year by year. The appended table shows, so far as statistics are available, the quantities imported from various countries and the amounts manufactured at home, each year since 1877. The rapid decline since 1888 of imports of English cement from 66.1 to 19.6 per cent. of total imports, and the contemporaneous increase of the imports from Germany from 28.0 to 49.4 per cent. is a tale with a moral. The increase in the quantities in the "Other Countries" column since 1894 may be accounted for by the increased import of Danish and Swedish cement.

But the most significant fact is the steady and rapid increase in the proportion of manufactured to imported cements since 1891. That proportion should and undoubtedly will be increased still more rapidly in the future. For years the American makers have had a hard struggle against strong adverse prejudice. The prejudice was at first well founded, since the early attempts to produce Portland cement here met with little better success than abroad. But, once established, it has been very hard to live it down. Portland cements, fully as good as any from Germany or any other country, have been made here for several years, but Americans are only beginning to realize the fact. As more attention is paid to cements and more care is taken in thoroughly testing and investigating them, the fact is growing apparent that, even though American Portlands are not always perfect, the chances of receiving a lot of imperfect cement are fully as great with the foreign as with the domestic article.

APPENDIX.—UNITED STATES PORTLAND CEMENT STATISTICS.

	Imports from										Total Bbls.	Manufactured in United States, Bbls.	Consumed. Bbls.	% Made U. S.
	England.		Germany.		France.		Belgium.		Other Countries.					
	Bbls.	%	Bbls.	%	Bbls.	%	Bbls.	%	Bbls.	%				
1877	....	....	....	....	....	....	....	....	....	....	58,450	....	....	....
1878	....	....	....	....	....	....	....	....	....	....	92,000	....	....	....
1879	....	....	....	....	....	....	....	....	....	....	106,000	....	....	....
1880	....	....	....	....	....	....	....	....	....	....	187,000	....	....	....
1881	....	....	....	....	....	....	....	....	....	....	221,000	....	....	....
1882	....	....	....	....	....	....	....	....	....	....	337,793	85,000	455,406	20.1
1883	....	....	....	....	....	....	....	....	....	....	472,864	90,000	462,864	16.0
1884	370,515	63.6	184,185	31.6	5,453	0.9	22,261	3.8	209	0.1	582,623	100,000	682,623	14 7
1885	270,356	46.8	267,800	46.3	1,451	0.2	35,073	6.1	3,461	0.6	578,141	150,000	728,141	20.6
1886	332,546	51.5	284,927	44.2	3,937	0.6	21,751	3.4	2,036	0.3	645,197	....	....	....
1887	621,367	57.5	427,510	39.6	4,854	0.5	22,673	2.1	3,540	0.3	1,079,944	....	....	....
1888	1,332,865	66.1	564,883	28.0	10,465	0.5	99,401	4.9	9,376	0.5	2,016,990	....	....	....
1889	943,866	62.2	484,824	31.9	3,957	0.3	81,336	5.4	3,367	0.2	1,517.350	....	....	....
1890	1,161,612	56 4	723,487	35.1	15,658	0.7	159,834	7.8	148	0.0	2,060,739	335,500	2,396,239	14.0
1891	1,336,858	47.6	922,007	32.8	10,364	0 4	533,927	19.0	4,663	0.2	2,807,819	454,813	3,262,632	13.9
1892	1,127,701	42.0	1,073,768	40.0	2,985	0 1	475,903	17.7	5,564	0 2	2,686,921	....	....	....
1893	....	....	....	....	....	....	....	....	....	....	2,674,149	590,652	3,264,801	18.2
1894	....	....	....	....	....	....	....	....	....	....	....	798,757	....	....
1895	806,884	26.9	1,299,914	43.4	22,837	0.8	708,875	23.6	158,880	5.3	2,997,395	990,324	3,987,719	25.3
1896	742,169	24.8	1,366,909	45 7	26,714	0.9	742,237	24.8	111,568	3.8	2,989,597	1,543,023	4,532,620	34.7
1897	460,592	19.6	1,160,905	49.4	32,124	1.4	645,780	27.5	48,619	2 1	2,348,020	2,304,300	4,652,320	49.9

The testing of cements for use upon works is just as important as the testing of steel for use in bridges or boilers, and to the failure to give careful attention to this point is due in a great measure the slowness of American consumers to appreciate the value of American Portlands. Probably in no other country in the world, producing or consuming large quantities of cement, is the spirit of investigation in this direction so little apparent. While England has no national system for testing cements, still fully 75 per cent. of the cement consumed is thoroughly tested by experts, and the same may be said of Holland. France, Belgium, Germany and Austria maintain Government testing stations where cement, among other engineering materials, receives careful attention. In this country more attention has been given to the matter of late, but still enormous quantities of cement are consumed concerning which the consumer knows absolutely nothing except the brand on the barrel or sack. The writer has met inspectors on works who "did not believe in testing," and who professed to be able to tell all about a cement by feeling it or tasting it. Many consumers who do test their cement limit their tests to fineness and a few neat briquettes broken at seven days old; and, with these two tests as their only criterion, they place the limits of strength in their specifications as high as they dare. This fact, coupled with the keen competition among makers, is a sore temptation to over-lime their product beyond a safe limit. It is greatly to be hoped that the present dawning of the days of careful tests will overcome this danger.

The following summary of amounts produced in, and exported from, the various countries of the world is as nearly correct as statistics available will permit:

CEMENT PRODUCTION OF THE WORLD.

	Output. Barrels.	%	Export. Barrels.
1. Germany	13,500,000	38.4	3,000,000
2. England	8,300,000	23.7	3,500,000
3. France	3,000,000	8.6	1,139,000
4. United States	2,300,000	6.6	
5. Belgium	2,250,000	6.4	1,500,000
6. Russia	2,000,000	5.7	
7. Austria	1,000,000	2.9	
8. Italy	800,000	2.3	
9. Norway and Sweden	500,000	1.4	100,000
10. Denmark	400,000	1.1	
11. All other countries (estimated)	1,000,000	2 9	
	35,050,000	100.0	9,239,000

The demand for Portland cement the world over is rapidly increasing. In all the principal producing countries the factories are overstocked with orders and hardly know how to fill them. European makers are not seeking the American market so anxiously, partly on this account and partly because they have to meet such fierce competition from the American factories. This fact, coupled with the increasing confidence in American brands, points toward a still greater diminution in imports from now on. The duty on cement is 8 cents per 100 pounds, or about 30 cents per barrel, and ocean freights amount to about 40 cents. The foreign Portlands must thus be produced at least 70 cents per barrel cheaper than at home to meet competition. Freights from our principal producing centers to New York are about 14 cents per barrel.

We have seen that England, though for years in the lead, eventually yielded first place in the Portland cement industry to Germany with its more careful and systematic methods. The United States has entered the field in comparatively recent years, and now holds fourth place in volume of output. The quantities are increasing annually by strides, while even yet the domestic supply is only one-half the consumption. It seems quite probable that the foreign brands will eventually be practically driven from the market; but may we not aspire to even greater things and hope that at no very distant date American manufacturers may, by their skill and ingenuity, so reduce the price, while maintaining the quality, that we shall see American Portland cements crossing the ocean and successfully competing with European brands in the markets of non-producing countries of Europe?

DISCUSSION.

Mr. S. J. Baker.—Can Mr. Green give us any data upon the consumption or output of natural cement?

Mr. Green.—I think it is about eight and one-third million barrels per annum in this country.

Mr. D. L. Clements.—I have enjoyed this paper very much; Mr. Green must have spent a large amount of time in preparing it. The outlook is certainly very encouraging to American cement manufacturers.

Mr. C. B. Stowe.—I am very much pleased with the statements Mr. Green has been able to make regarding the advancement of the cement industry in this country. I think that there is no question that we are going not only to equal, but to surpass foreign cements in quality. I had a letter last spring from Mr.

White, of London, and he admits that we are ahead of England now. He thinks they can equal the quality of our cement in England, but the only way for them to hold up against the American trade is to become American manufacturers themselves. I think we have made great advance during the past year, and are likely to show much more before we get through.

Mr. E. E. Boalt.—It has been my pleasure, in the engineering office of this city, to be very closely connected with the use of both Portland and natural cement, especially in tests. The paper has been devoted to its manufacture, and the subject has been very ably presented. I hope Mr. Stowe can give us a little information relative to the new plant he has lately put into operation, and the new methods. One feature I have in mind is the fine grinding, by a process of which, I believe, Mr. Stowe is the inventor. When the grinding can be made so complete that a barrel shall contain no unreduced particles, the quality of the cement will be greatly improved. But this is only one feature. To produce perfect cement we must take the materials in proper chemical proportions, and give them a perfect mixture, a perfect burn and a perfect grind.

Mr. J. C. Robinson.—Where extreme fineness is required, it cannot be had by the use of screens. It is impracticable to use a screen finer than a 200 mesh. I believe that, whether Griffin mills or Ball mills are used, or any other of that kind, the cement is going to be finished in the tube mills.

Mr. Stowe.—I found some curious things in testing German and English cements. About 60 per cent. would pass through a 200 mesh sieve, and about 80 per cent. through one of 100 mesh, so that one really buys 60 per cent. of cement and 40 per cent. of grit or sand. We have been making some tests in order to ascertain the point of fineness at which cement really is cement and ceases to be sand. It lies somewhere between a mesh of 200 and one of 400. If it lies at 300 mesh, a barrel of foreign cement contains only about 50 per cent. of true cement. We have also found that much depends upon the mixing of materials before burning, and that the strength is about in proportion to the amount of mixing; that is, for a fineness of 200. We have had some clinkers from which a sand test would go higher than a neat test. Neat cement may be so fine that in a neat test it will crystallize in such a way as not to carry the strength. As I look at it, the grinding of cement is yet in its infancy. I had a letter from Professor Johnson, of Washington University, who remarked how little we yet know about Portland cement. But there are going to be great improvements in this line. I believe that in ten years from this

time we shall be making cement mortar that will contain four times the proportion of sand it contains to-day and still give the same strength. We have the best of materials in this country. There is, in Arkansas, at White Cliffs, a mountain of a thousand acres, which rises about 300 feet. There is enough raw material there to supply the world a good many years. Finer material could not be found than that in the beds in this country. The Portland cement business in this country has been a series of failures, but I think we are going to come out ahead and some one is going to make some money out of it; but it will probably be the man who starts in later.


ASSOCIATION OF ENGINEERING SOCIETIES
Longitude West from Greenwich
CANADA
MEXICO
GULF OF MEXICO
PACIFIC OCEAN
ATLANTIC OCEAN
MONTANA
DENVER
PACIFIC COAST
MINNEAPOLIS
ST. PAUL
ST LOUIS
DETROIT
CLEVELAND
BUFFALO
BOSTON
Philadelphia
VIRGINIA
WASH.
ORE.
IDAHO
MONT.
WYO.
CAL.
NEV.
UTAH
COLO.
ARIZ.
N. MEX.
N. DAK.
S. DAK.
NEBR.
KAN.
OKLA.
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MINN.
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WIS.
MICH.
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OHIO
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TENN.
MISS.
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GA.
FLA.
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DEL.
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Association of Engineering Societies.

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PROCEEDINGS.

Technical Society of the Pacific Coast.

Regular Meeting, San Francisco, January 7, 1898.—Called to order at 8.30 p.m. by Director D. C. Henny.

The minutes of the last regular meeting were read and approved.

The nominating committee reported as follows:

Your committee on nominations for officers of the Society for the year 1898, begs to submit the following ticket:

For President—E. J. Molera.
For Vice-President—G. W. Percy.
For Secretary—Otto von Geldern.
For Treasurer—E. T. Schild.
For Directors—D. C. Henny, Hermann Barth, Louis Falkenau, T. W. Ransom, John H. Wallace.

Respectfully,

Luther Wagoner,
Chairman of Committee.

The ticket was ordered printed and distributed for ballot in accordance with the By-Laws of the Society.

Mr. G. W. Percy addressed the Society on the subject of "Modern Fire Proofing," which was discussed.

Adjourned.

Otto von Geldern, *Secretary.*

Annual Meeting, January 21, 1898.—Called to order by Director Percy.

After appointing tellers the votes for officers were counted, whereupon the Chair announced that the following ticket had been unanimously elected: President, E. J. Molera; Vice-President, G. W. Percy; Secretary, Otto von Geldern; Treasurer, Edward T. Schild; Directors, Hermann Barth, L. Falkenau, D. C. Henny, T. W. Ransom, and John H. Wallace.

The Secretary and Treasurer read their annual reports, which were ordered received and placed on file.

Adjourned.

Otto von Geldern, *Secretary.*

Detroit Engineering Society.

Detroit, Mich., January 21, 1898.—The regular monthly meeting was held at the Hotel Ste. Claire, President Jesse M. Smith presiding, with twenty-one members and eleven visitors present, including representatives of the Michigan Chapter, American Institute of Architects, in attendance by special invitation. The paper of the evening, entitled "Decorative Marbles," was read by Mr. W. M. Courtis, member American Institute Mining Engineers, and extensively illustrated by samples from the leading quarries of America and the prominent buildings of Ancient Rome. It was discussed by Messrs. Smith, Mason, Donaldson, Goldmark, Pettee, Rogers, Dow and Courtis.

The President announced the first death in the ranks of the Society, that of Mr. Gouverneur Morris, member American Society Civil Engineers, which occurred on the night of December 30, at his residence, and upon motion appointed Messrs. Wisner, Hinchman and the Secretary a committee to prepare suitable resolutions and memoir.

Messrs. Joseph H. Ames, F. S. Bigler, Fred. R. Steel and W. E. S. Strong being reported upon favorably were elected to resident membership. The names of Messrs. M. Woolsey Campau and Andrew H. Greene, Jr., were proposed for membership and referred to the Executive Committee.

A resolution of thanks from Michigan Chapter, American Institute of Architects, and an invitation for a series of lectures from the Architectural Sketch Club were read, and on resolution the thanks of the Society were ordered extended to the latter organization. A paper by Mr. J. W. Shaub, member St. Louis Engineers' Club, on "A Permanent Roadway for Railroads," was announced for the February meeting. Adjourned.

Gardner S. Williams, *Secretary.*

At a meeting of the Executive Committee, held at Room 36, Moffat Block, January 21, bills to the amount of $4.02 were ordered paid and candidates for membership favorably voted upon, and the resignation of membership of Mr. S. F. Dibble accepted.

Gardner S. Williams, *Secretary.*

Civil Engineers' Society of St. Paul.

St. Paul, Minn., January 3, 1898.—The fifteenth annual meeting of the Civil Engineers' Society of St. Paul was held at the Windsor Hotel at 8.30 p.m. Present, nineteen members and eleven visitors. Vice-President Crosby in the chair. Minutes of previous meeting read and approved. Article III of the Constitution was, by final vote, amended to read as follows:

"Any civil, electrical, mining or military engineer, and any architect, metallurgist, assayer or surveyor holding an appropriate degree conferred by any incorporated college or university, or any graduate of the United States Military or Naval Academies who shall have practiced his profession for one year or longer, or who, not holding such degree, shall have practiced his profession for five years or longer, shall be eligible to membership

in this Society. Persons chosen from the classes mentioned in this article shall be called members.

"Students of engineering and other persons who intend to adopt one or more of the branches of the profession that are mentioned in the last preceding paragraph, but who are ineligible for full membership, may be chosen as juniors. They shall have all the privileges of members except the right to vote.

"Associate members may be chosen from among persons whose interest in pure science, or in the applications of science, may lead them to desire connection with the Society. They shall have all the privileges of members except the right to vote.

"Honorary members may be chosen. They shall be men eminent in science, or men who have conferred some signal benefit on this Society. They shall be free from all fees and assessments."

The reports of the Secretary, Treasurer and Librarian were read and accepted. The Treasurer was authorized to pay Custodian Ames $10 for supervision of care of Society's room in the Court House. The Secretary was instructed to request the Secretary of the Association to furnish the Society with five copies of the JOURNAL of the Association. Of these five copies, the Librarian was directed to furnish one bound volume each to the Minnesota State Historical Society, the St. Paul Public Library and the library of the Society. The remaining two copies are to be disposed of at the Librarian's discretion.

Officers were elected for the ensuing year as follows: President, J. D. Estabrook; Vice-President, Oliver Crosby; Secretary, C. L. Annan; Treasurer, A. O. Powell; Librarian, A. W. Munster; Representative on Board of Managers of the Association of Engineering Societies, E. E. Woodman.

At 10 o'clock the meeting adjourned to the banquet room to discuss a substantial bill of fare. The last toast was responded to in the early morning.

C. L. ANNAN, *Secretary.*

Engineers' Club of Minneapolis.

MINNEAPOLIS, APRIL, 1897.—As directed by the meeting of February 23, the President and Secretary arranged for the meeting of the members of our Club and the Civil Engineers' Society of St. Paul at the east end of the Tenth Avenue South Bridge, from which point a visit was made to the St. Anthony Falls Water Power Company's new dam, Mr. Wm. de la Barre and his assistants explaining the points of interest in the dam, among which were several bear trap dams; and also the electric power house and plant.

The water in the river was unprecedentedly high, and the ice had carried over the dam, a day or so before, booms, boom piles and piers or cribs filled with stone, which had struck the coping and carried out a part of the top of the center of the dam; and it was impossible to make as thorough an examination of the dam as was desired.

Thirteen members of the Minneapolis Club, eleven of the St. Paul Society and six guests composed the party.

ELBERT NEXSEN, *Secretary.*

MINNEAPOLIS, JUNE 22, 1897.—A meeting was held in the Council Committee Room, City Hall. As but four members were present, the reading and discussion of Mr. Frank J. Llewellyn's paper on "Coal Handling Appliances" was postponed.

The Secretary announced the names of the following: Rennie B. Fanning, L. S. Gillette, W. C. Weeks, James B. Gilman and J. F. Richards as proposed for membership by W. R. Hoag and F. J. Llewellyn.

ELBERT NEXSEN, *Secretary*.

MINNEAPOLIS, AUGUST 7, 1897.—By invitation of Mr. F. W. Cappelen, as City Engineer, thirteen members of the Engineers' Club of Minneapolis, nine members of the Civil Engineers Society of St. Paul and seven visitors met at the City Hall at 2 P.M. and proceeded on special cars to Thirty-seventh avenue, Northeast, and Central avenue, from which point they inspected the laying of the two 50-inch riveted steel water mains and the 16-inch cast-iron drain pipe laid in the same ditch to the reservoir, which they connect with the North Side Pumping Station.

After inspecting the reservoirs and partaking of a lunch, the names of W. E. Stoopes, proposed for membership by W. M. Fox, and F. W. Cappelen, and Albert Graber by Elbert Nexsen and W. R. Hoag, were announced by the Secretary; and the party returned by special cars.

ELBERT NEXSEN, *Secretary*.

MINNEAPOLIS, JANUARY 3, 1898.—By invitation of the Civil Engineers' Society of St. Paul, members of our Club attended their annual meeting at 8 P.M. and banquet at 10 P.M., at the Windsor Hotel, St. Paul.

ELBERT NEXSEN, *Secretary*.

MINNEAPOLIS, JANUARY 10, 1898.—The meeting was called to order at 8 P.M., at the Nicollet House, by President F. J. Llewellyn; sixteen members, eight visitors from St. Paul Society and twenty-nine from Minneapolis were present.

The minutes of previous meetings read and approved.

The following were unanimously elected to membership: Ellis J. Woolf, Harry E. Smith, J. E. Carroll (proposed February 23, 1897), Rennie B. Fanning, L. S. Gillette, W. C. Weeks, James B. Gilman, J. F. Richards (proposed June 22, 1897), W. E. Stoopes and Albert Graber (proposed August 7, 1897), and their election announced by the President.

Mr. F. J. Llewellyn then entertained the Club for an hour and a quarter by a paper on a trip to the Yellowstone Park, illustrated by about fifty stereopticon views of the park, many of which he took himself. After an informal discussion, a light lunch was served and an entirely informal hour enjoyed by those present.

ELBERT NEXSEN, *Secretary*.

Civil Engineers' Club of Cleveland.

CLEVELAND, JANUARY 11, 1898.—The regular meeting of the Club was held in its room in Case Library, January 11, at 7.45 P.M., with President Ritchie in the chair. Present, forty-seven members and six visitors.

The minutes of the last meeting were read and approved.

The President appointed M. W. Kingsley and James McIntyre tellers

to canvass the vote cast for members and officers. Upon receiving the report of the tellers, the President announced the election of Stanley R. Greene to active membership, and declared Wm. H. Searles elected Secretary and Joseph R. Oldham second director for the unexpired term.

The Executive Board reported that the resignations of Messrs. J. F. Brown, Cecil L. Saunders and Jonathan Wainwright, former active members of the Club, had been accepted. It further reported upon the application of Henry W. Guthrie for associate membership, and the application was read.

The committee appointed to prepare a memorial in honor of the late Secretary, Forrest A. Coburn, presented and read their report, which is as follows:

"Being called upon to mourn the loss of a valued friend and fellow member of this Club, we offer the following tribute to his memory:

"We wish to testify that in Forrest A. Coburn, the Civil Engineers' Club of Cleveland has lost one of its most honored members. For many years he was with us, and from the first it was evident that we were associating with one of sterling character and large ability. His genial, hearty manner won for him not only our regard, but our warmest sympathy and affection.

"He was one who interested himself actively in our work. He was a frequent attendant at our meetings, and was ever ready to offer suggestions drawn from his many years of practical experience. At our picnics and social gatherings he was among the most jovial of all, entering heartily into the sports and games.

"As Secretary of our Club he was constantly faithful, nearly always present until his final illness prevented him. The work we had appointed him to do was being done accurately, carefully and cheerfully. He felt greatly honored by the fact that the Club had called him to the Secretaryship; and on our side we felt that he honored us and the office by assuming its duties, especially so when we considered that he was one of our busiest men.

"It was one of his sterling traits that no matter how busy he might be himself, he was ever ready to do for others.

"He took a broad view of everything connected with the Club. He believed that the sister professions of architecture and engineering were, as they should be, largely helpful and necessary to each other. Perhaps to the cordiality of his views on this subject may be attributed in a large measure the warm regard with which he was held by the Club. We recall with pleasure his extreme hopefulness and his large-hearted views as to the welfare of this body.

"He was among the most active in agitating the problem of how to secure a better home for the Club. He was also more than ordinarily interested in the establishment of more intimate and cordial relations between the numerous scientific societies of our city.

"Now that he has departed from us do we especially realize these points of his character. He will live in our memory, and by those who personally knew him he will ever be sincerely mourned.

"To his bereaved family we offer our deepest sympathy and consolation.

(Signed) John Richardson,
Chas. W. Hopkinson,
Jos. C. Beardsley,
Committee.

Cleveland, January 11, 1898."

Mr. W. R. Warner moved that the report of the committee be adopted and spread upon the minutes, and that a copy be sent to the family of the deceased. The motion was carried by a rising vote.

This being the meeting at which a nominating committee should be selected, the following names were proposed: Ambrose Swasey, M. E. Rawson, A. H. Porter, J. L. Gobeille and W. R. Warner. There being no other names proposed, it was moved and carried that the Secretary be instructed to cast the vote of the Club for these gentlemen as a nominating committee. The Secretary reported the vote so cast.

Several amendments to the Constitution were presented in writing, signed by James Ritchie, Frank C. Osborn, Hiram Kimball and Wm. H. Searles. The amendments were read and discussed, and without alteration were ordered to letter ballot.

The Club then had the pleasure of listening to an address by Mr. M. S. Greenough, member American Society Civil Engineers, upon the subject of "Modern Gas Plants."

Mr. Greenough briefly reviewed the history of the gas manufacturing industry since its first inception near the beginning of the century, and illustrated some of its more important and recent developments. He described the works of the Cleveland Gas Light and Coke Company, of which he is president and general manager, located at the foot of Willson avenue. He described a modern regenerative retort in which a very high degree of heat is maintained, and the heat produced thoroughly utilized in a most economical manner. He also described and illustrated the purifying boxes which are at present employed. He described the modern gas holder and frame, which has developed very large proportions and the construction of which has become an important engineering problem. The lecturer also described a variety of labor-saving machinery by which a considerable economy in the working of the plant is realized, such as apparatus for coal raising and charging, for coke handling and sorting, etc. He described the Coventry inclined retorts, for the manufacture of gas by a continuous process which is aided by gravity.

Leaving the subject of coal gas manufacture, he proceeded to the discussion of so-called water gas, and described some works designed for its manufacture.

In conclusion, he illustrated upon a map of the city the system of distribution employed, and described the means by which a nearly uniform pressure is maintained under the extremely varying rate of consumption during the hours of the day and night.

The discussion which followed was opened by Mr. W. R. Warner, who asked the speaker to kindly give some information regarding meters. To this Mr. Greenough replied in effect that about 20,000 meters are now in use in the city of Cleveland, all of which had been tested by the company at least once, and several of them several times. Seventy per cent. of the whole number are within two per cent. of exactitude, some being fast and others slow. The number of those slow is about twice as great as that of those fast. The discussion was continued by Messrs. E. P. Roberts, W. C. Parmley, Richard L. Newman and Prof. C. F. Mabery. At the close of the discussion, Mr. Warner moved that the thanks of the Club be expressed to Mr. Greenough for his very comprehensive, instructive and interesting lecture, which was carried, and the Club adjourned.

Wm. H. Searles, *Secretary.*

Cleveland, January 25, 1898.—The semi-monthly meeting of the Club was held in its room in Case Library at 7.45 p.m.; with President Ritchie in the chair. Present, thirty-three members and nine visitors.

The minutes of the last meeting were read and approved.

Mr. Louis J. Germain not being present at the hour appointed for him, Mr. Samuel T. Dodd proceeded at once to read his paper on the subject of "Power Consumption on Electric Railroads."

He discussed the resistance developed by moving cars, and reviewed the formulas which have been in common use to express this resistance; and compared these results with a number of recent instances upon electric railroads. He concluded that modern experience shows that the old formulas, while giving results rather high at low velocities, give too small resistance at high velocities when applied to electric motors. The author also discussed the question of acceleration, and the power required to bring the car to a certain maximum velocity, and the number of seconds in which this may be accomplished. He adduced instances from the practice of several of the interurban roads about Cleveland, and showed that about 400 pounds per ton was the maximum horizontal effort to be expected from the electric motor. The paper was accompanied with a number of diagrams and tables illustrating the subject.

The discussion was participated in by Messrs. W. H. Searles, James Ritchie, Joseph R. Oldham and Walter C. Parmley, members of the Club; also by Messrs. L. M. Sheldon and George M. Hoag, visitors.

Mr. Germain, who is an engineer of the old school, being a venerable man over eighty years of age, but well preserved in body and still active in his mental faculties, then addressed the Club, and gave some outlines of a method by which he would utilize the current of flowing streams to obtain power for generating electricity or other purposes. In this connection he had in mind the utilization of the River Jordan, which has a rapid descent, although devoid of waterfalls at any one point. He also described a plan he had for cooling the stoke hole of an ocean steamer by distributing the current of cool air under the floor, allowing it to flow upwards through numerous openings.

Wm. H. Searles, *Secretary*.

Montana Society of Engineers.

Annual Meeting, January 6-8, 1898.—Assembled in the City of Butte, Montana.

On January 6, 1898, the members visited the Gagnon, Never Sweat and St. Lawrence Mines. Afterward a drive was taken to the new School of Mines, a State institution most favorably located, Butte being famous as the principal copper producer in the world, and prior to '93 as a great silver producer. Here can be seen the greatest advancement in the methods of mining and milling and the most modern machinery for such work.

On January 7th, at 10 a.m., the members boarded a special train furnished by the Oregon Short Line Railway Company. Arriving at Divide Station, carriages in waiting conveyed them two miles to the Big Hole Dam. At the dam they were greeted very hospitably by Messrs. Winters & Parsons, the contractors, and Mr. M. S. Parker, the engineer in charge. Mrs. Winters and Mrs. Parsons served a sumptuous luncheon and each

member was presented with a beautiful souvenir of the occasion in the shape of views of the dam. The dam is being constructed by the Montana Power Company, to furnish electrical power to Butte City, distant 28 miles.

On January 8th, in the forenoon, the members visited a number of the mines and smelters in Butte.

The 11th Annual Meeting of the Montana Society of Engineers was held in the Council Chamber of the City Hall at Butte, Montana, on January 8, 1898.

The meeting was called to order at 2 P.M., with President Charles W. Goodale in the chair. Mr. James S. Keerl acting as Secretary *pro tem.*, the minutes of the last monthly meeting were reau and approved.

The application for membership of Mr. William E. Donovan, architect of the School of Mines building, Butte, Montana, was favorably considered.

Messrs. Gillie and Taylor were then appointed tellers to canvass the ballots for membership. Messrs. MacFarlane and McNeill were appointed to canvass the ballots for officers.

The Secretary's report was then called for. Some of the items were as follows:

Amount in treasury, January 9, 1897	$82.78	
Receipts for year 1897	759.50	
Total		$842.28
Amount paid out for bills contracted in 1896	$152.06	
Amount paid out for bills contracted in 1897	617.86	
Total amount paid out during year		$769.92
Balance in treasury		72.36
Amount of bills unpaid		94.00
Amount due Society from members		282.00

MEMBERSHIP IN 1897:

Active	Beginning of year,	59	Close of year,	96
Honorary	" "	2	" "	4
Associate	" "	16	" "	12
Total	" "	77	" "	112

During the year 2 associate members have returned to active membership, 3 suspended members have been reinstated, and 32 new members have been added, making a total addition of 37 to active membership. Two associate members, Messrs. William A. Haven and Edwin H. McHenry, became honorary members by election.

The report of the Librarian shows a number of additions to the library. The Society receives 21 periodicals.

The Librarian urged the necessity of additional bookcases, and stated that the library should receive more attention than in the past, and that he considered it a mistake to combine the offices of Secretary and Librarian. The office of Librarian, if properly conducted, was sufficient to keep the Librarian busy.

The report of the Treasurer agreed with the Secretary's report as to amounts of money received and expended.

Both reports were received and referred to the Board of Trustees.

The ballots showed that Mr. Milo Smith Ketchum had been elected to membership, 33 votes, all affirmative, having been cast.

The officers elected for the ensuing year were as follows: President, James M. Page, of Pageville; First Vice-President, Maurice S. Parker, of Divide; Second Vice-President, Forrest J. Smith, of Helena; Secretary and Librarian, Albert S. Hovey, of Helena; for Treasurer and Member of Board of Managers of the Association of Engineering Societies, James S. Keerl, of Helena; Trustee for 3 years, Edward R. McNeill.

The new officers were installed.

President Page, upon taking the chair, thanked the Society for the honor conferred.

Mr. Eugene Carroll, of the Committee of Arrangements, then reported. He moved that the Committee of Arrangements be appointed at the November instead of at the December meeting, in order to give the committee more time to make arrangements. Carried.

Mr. Carroll stated that the Society has been tendered many courtesies by the mining companies and railroads, and he moved that the Secretary be notified to convey the thanks of the Society to the following gentlemen and corporations: Messrs. W. H. Bancroft and J. P. O'Melveney, General Manager and Chief Engineer, respectively, of the Oregon Short Line Railway Company; to Mr. Charles W. Goodale and the Colorado Smelting and Mining Company; to Mr. August Christian and Mr. McKinna, Chief Engineer and Master Mechanic, respectively, of the Anaconda Copper Mining Company; to Messrs. J. G. Link and W. E. Donovan, architects of the School of Mines; to Messrs. Winters & Parsons, contractors, and Mr. M. S. Parker, engineer of the Montana Power Company; to Messrs. Frank Klepetko and C. S. Batterman, of the Boston and Montana Mining Company; to Mr. J. R. Wharton, Receiver of the Butte Street Railway Company; to the Montana Ore Purchasing Company, and Mr. R. D. Grant, General Manager of the Parrot Mining Company, and to Mr. John F. Davies, Librarian of the Butte Free Public Library. Motion carried.

Mr. John Herron moved that the thanks of the Society be also extended to Messrs. E. H. Wilson, Eugene Carroll and J. S. Keerl, members of the Committee of Arrangements, for their successful handling of this meeting. Mr. Carroll moved that Mr. Charles W. Goodale be also added to the list, as he has been our mainstay in the making of arrangements. Mr. Wilson moved that Mayor Harrington, of the City of Butte, who has so kindly extended the courtesy of furnishing a place of meeting for our Society, be added to the list. Mr. Herron's motion, as amended, was unanimously carried.

A motion by Mr. J. S. Keerl was carried, that a vote of thanks be tendered to Mr. Charles W. Goodale for taking such an active interest in the affairs of the Society,—an interest which has contributed so much to its present successful condition. Carried. The Secretary wishes to thank Mr. Keerl and the Society for a similar recognition of his labors for the past year.

A motion prevailed that a committee of three, with the President as Chairman, be appointed as a Committee on Transportation. Messrs. Charles W. Goodale, Eugene Carroll and John Herron were appointed on the committee.

The retiring President now delivered the annual address. It was a summary of engineering progress in the State during the past year. He

spoke of the dam of the Big Hole River, which the Society had visited the day before, of the Missouri River dam, which is to develop electrical power to be transmitted to Helena, 19 miles distant; of the Gaylord and Ruby Valley Railway, now being equipped, and of various other railway improvements and constructions in the State. In conclusion, he urged the members to increase the interest in the Society by presenting more papers. He did not consider the excuse of having no time to be the real cause.

Mr. T. M. Ripley, engineer of the Missouri River dam, then read a paper in regard to that great enterprise. The following is an abstract of the discussion of this paper.

Mr. Wilson.—I believe it is eminently proper for our Society to endeavor to get Montana into line with most of the other Western States in the appointment of a State Engineer, who shall have close supervision over all structures that are intended to impound or raise water. Our neighboring State, Idaho, has an admirable system, which is being carried into effect. The State Engineer has the inspection of all the plants in course of construction which are intended to raise water more than 10 feet from the surface, and has supervision over all large plants built.

In our State, in the near future, a great many reservoirs will be built to store water for irrigation. These, if not properly built, would imperil property below, exposing towns and cities to destruction. No supervision of these structures is now provided.

Mr. Carroll.—I agree with Mr. Wilson that the Society should make an effort in this line. I had a little experience of my own when we began the construction of our large masonry dam south of Butte. The people below were very much excited at our imperiling the life (as they expressed it) of all Butte. The County Commissioners inspected the structure, and the worthy Chairman, Mr. John Caplice, said it was all right, and thus public fear was allayed. It would be much better to have a State Engineer to watch and superintend the construction in such cases.

This is a very important matter when we consider that two-thirds of the agricultural country must eventually be irrigated through the storage system, which is now in its infancy.

President Page spoke strongly in favor of the establishment of the office of State Engineer. He said the era of dam construction has just begun in Montana, and eventually nearly all the cities must be supplied by the storage system. Before any more great enterprises of the sort are started there should be a State Engineer to see that they are properly constructed.

Mr. Blackford made a motion that the President appoint a committee of three to prepare a bill, to come before the next Legislature, providing for the creation of the office of State Engineer and defining his duties, the bill to be presented at the next annual meeting of the Society for discussion, then to be presented to the Legislature. Motion carried.

A paper on road improvements, by Mr. F. H. Ray, who represents the League of American Wheelmen, was read. Mr. Ray presented the Society with two books, "Country Roads" and "Macadam Roads," containing the latest methods of road building. The President called upon Hon. Frederick Whiteside, of Flathead Co. Mr. Whiteside thanked the Society for courtesies extended, and stated that road building contained so much of commonplace and so little of higher engineering that the matter was often overlooked by engineering societies. He was therefore pleased that the

Montana Society of Engineers had taken up the matter in earnest. At the beginning of this century, road building in a systematic manner was commenced in this country, and several important roads running through Maryland and Virginia, called National Highways, were well built, and are in existence to-day. Upon the advent of railroads, public highways were neglected. In the West we have kept but little in advance of the Indians in road improvements. Good roads are an index of civilization. Railroads are necessary for long transportation, but we need good highways for the transportation of our produce to the railroads. Over $75,000,000 are expended annually in this country upon our roads, and yet, through unsystematic methods, we have but little to show for this enormous expenditure, the roads being kept simply in a passable condition. If the amount expended in the past had been put into good, permanent improvements we should now have roads in the oldest sections of the country on which we could nearly double the loads.

The cost of wagon transportation in this country per annum is over $600,000,000. At least one-half of this vast amount could be saved if our road funds were properly expended. The Macadam system of road building is doubtless the best, both on account of cheapness in construction and of its smoothness and durability.

Legislation is necessary to bring about uniformity in road improvements. But little can be expected from local boards differing widely in their methods of construction. Place the roads under the superintendence of one strong central power, as was done during the Roman Empire and by Napoleon, and, with no greater expenditure than under the present system, we would soon have roads that would be a credit to the country.

The speaker favored the employment of State convicts on road construction. Roads can be built much cheaper in our State than in many of the Eastern States, for nature has given us the best of material. The speaker favored a State Highway Commission, composed of 3 or 5 members, who should have power to plan a general system. They should have power to employ a chief engineer, under whom should be placed local or resident engineers.

Some of the Eastern States are greatly improving their methods of road construction. To the advent of the bicycle we are largely indebted for a new era in road building. The League of American Wheelmen is vigorously agitating road improvements. He hoped the time would soon come when a wheelman can ride across Montana without carrying his wheel a large part of the distance.

Mr. McNeill stated that his views were entirely in accord with those of Mr. Whiteside, but the great obstacle was the lack of money. Montana's taxable property is small, and Mr. McNeill could not see where the money was to come from, at the present time, to construct Macadam highways across a State of such enormous proportions as Montana. The subject was further discussed by Prof. Kerr and others, and finally, through the motion of Mr. Carroll, referred to the committee appointed to present the matter of creating the office of State Engineer, with the request that Mr. Whiteside be requested to co-operate with such committee. Mr. Goodale then read a letter from past-President W. A. Haven. A motion to adjourn prevailed, to meet again in the banquet hall of the McDermott Hotel at 9 P.M.

In the large dining-room of the McDermott Hotel about 50 members

and guests were seated. The dining-room was handsomely decorated with plants and cut flowers, and the gathering was enlivened by music. An elegant menu was served. Toasts were responded to as follows: "Our Guests," by Mr. E. H. Wilson; "The City of Butte," by Judge Stephen DeWolfe; "The Press," by J. H. Durston; "Montana," by A. B. Keith; "Hydraulic Engineering," by Professor C. H. Moore; "The Railroads," by Major J. E. Dawson and W. M. Tuohy; "Electrical Engineering," by H. W. Turner; "Engineering by Bull Train," by George W. Irwin; "The Architects," by H. M. Patterson; "Montana Society of Engineers," by President James M. Page; "Public Highways," by Fred. Whiteside; "Intercolonial Affairs," by John Maginnis; "Metallurgy and Engineering," by Jas. H. Kerr; "The Veteran Smelter Manager of Butte," R. D. Grant.

A. S. Hovey, *Secretary.*

Engineers' Club of St. Louis.

464th Meeting, January 5, 1898.—The meeting was called to order at 8 p.m., at 1600 Lucas Place; with President Bryan in the chair. Twenty-nine members and six visitors were present. The minutes of the 462d and 463d meetings of the Club and the 250th meeting of the Executive Committee were read and approved.

The applications for membership of Messrs. Hiram Martin Chittenden and John Broome Guinn, having been approved by the Executive Committee, these gentlemen were balloted for and elected members of the Club.

The Secretary announced that during the year 1897 he had received resignations from Messrs. Robert H. McMath, John H. Maxon, C. M. Woodward and J. L. Van Ornum.

The paper of the evening, by Mr. Richard McCulloch, was then read. It was entitled "An Historical Sketch of Street Railways." The development of the street railway from the first road in New York City in 1832 was traced. The early experiments with mechanical traction and the history of the pioneer roads was given. The general improvements in street railway construction was traced down to the present time. The local history of the St. Louis roads was then taken up. A short sketch of the omnibus lines, which preceded the street railways, was given, and the history of the early horse railways was outlined. The first cable roads and the early electric roads were described, and the paper closed with a review of the present condition of the street railways.

The discussion which followed the reading of this paper was participated in by Messrs. Sturgeon, Eayres, Perkins, Harrington, Ockerson, Hermann and Johnson.

There being no other business, the meeting adjourned to another room, where lunch was served.

Richard McCulloch, *Secretary.*

465th Meeting, January 19, 1898.—The meeting was called to order at 8 p.m., at 1600 Lucas Place; with President Bryan in the chair. Nineteen members and two visitors were present. The minutes of the 464th regular meeting and of the 248th and 249th meetings of the Executive Committee were read and approved.

The Secretary announced that the following contributions to the library had been received:

Bulletin and Proceedings for 1897, International Railway Congress; presented by Mr. George B. Leighton.

History and Description of the Water Supply of Brooklyn; presented by Mr. I. M. de Varona.

The Croton Aqueduct and the Water Supply of Brooklyn; presented by Mr. M. L. Holman.

Maps showing the growth of the City of St. Louis; presented by Mr. A. N. Milner.

Report of the Sixteenth Annual Street Railway Convention; presented by Mr. Richard McCulloch.

Volume IV of *Engineering News;* presented by Mr. B. L. Crosby.

Pamphlet on a method of measuring wind pressure; presented by Prof. F. E. Nipher.

The paper of the evening, entitled "Experiments with a New Machine for Testing Materials by Impact," was then read by Mr. S. Bent Russell. The paper opened with a discussion of the subject of resilience. A description was given of the usual methods of testing materials by impact, and drawings of the new machine were exhibited. The method by which the machine had been calibrated and tested was given. Tables of tests on different materials, drawings, samples of broken specimens and cutters used in forming test bars were exhibited.

An informal discussion followed the reading of this paper, after which the meeting adjourned.

RICHARD MCCULLOCH, *Secretary.*

466TH MEETING, FEBRUARY 2, 1898.—The meeting was called to order at 8 P.M., at 1600 Lucas Place; with President Bryan in the chair. Thirty-six members and sixteen visitors were present. The minutes of the 465th regular meeting and of the 251st meeting of the Executive Committee were read and approved.

The Secretary announced that he had received an application for membership from Mr. Elliott Jones, President of the Manhattan Electric Company.

The report of the Executive Committee for the year 1897 was then read.

The Secretary announced the following programme of papers for the year 1898:

PROGRAMME FOR THE YEAR 1898.

January 5, "An Historical Sketch of Street Railways," R. McCulloch; January 18, "Experiments with a New Machine for Testing Materials by Impact," S. Bent Russell; February 2, "The Diesel Motor," Col. E. D. Meier; February 16, "Recent Advances in Electric Railway Practice," R. McCulloch; March 2, "Recent Improvements in Steam Ferries," Wm. H. Bryan; March 16, "The St. Louis Coliseum," E. W. Sterne; April 8, "U. S. Dredge Boats, Epsilon and Zeta," Edward Flad; April 20, "A Modern Telephone Exchange," Fred. E. Bausch; May 4, "Filtration of Water," M. L. Holman; May 18, "The Recently Discovered Oil Fields of Texas," Thos. D. Miller; June 1, "Ethics of Engineering," "Report of the Committee on Smoke Prevention," Chas. C. Brown.

SUMMER RECESS.

September 21, "Modern Central Lighting Stations," H. H. Humphrey; October 5, "Repairs to the Mill Creek Sewer," B. H. Colby; October 18,

"The Streets of a Modern City," A. N. Milner; November 2, "Roadways," Thos. H. Macklin; November 16, "Concrete Walls," Robert Moore; December 7, Annual Meeting, Reports of Officers and Committees; December 21, Annual Dinner.

The paper of the evening by Col. E. D. Meier, on "The Diesel Motor" was then read. The development of heat engines from their invention was traced, and the causes for the universal adoption of the steam engine as a heat motor were analysed. The writer stated that the steam engine had now reached the limit of its efficiency, and gave the reasons for its low efficiency as a transformer of energy. Gas and oil engines were described and their merits discussed. The principles on which depend the action of the Diesel motor were given, with a description of the machine as built in Germany. Data was given as to the relative efficiency of the Diesel motor as compared with the steam engine. The paper was illustrated by drawings, cuts and photographs.

The discussion which followed was participated in by Messrs. Bryan, Kinealy, Robert Moore, Johnson and Freeman.

There being no further business the meeting adjourned to another room, where lunch was served.

Richard McCulloch, *Secretary.*

Boston Society of Civil Engineers.

January 26, 1898.—A regular meeting of the Society was held at Chipman Hall, Tremont Temple, Boston, at 7.45 p.m.; President Dexter Brackett in the chair; ninety-one members and visitors present.

The record of the last meeting was read and approved.

Messrs. Henry V. Macksey and J. Herbert Shedd were elected members of the Society.

On motion of Mr. Stearns, it was voted that a committee of three be elected, by nomination from the floor, to report to the meeting the names of five members to serve as a committee to nominate officers for the ensuing year. Messrs. R. A. Hale, A. H. French and Henry Manley were nominated and elected as this committee. Later in the meeting the following names were reported for members of the Nominating Committee: Desmond FitzGerald, G. T. Sampson, H. F. Bryant, Sidney Smith and F. L. Fuller, and they were unanimously chosen by the Society.

It was voted that the usual committee (Mr. Henry Manley) be requested to make the necessary arrangements for the annual dinner of the Society, and that the usual appropriation be made for the incidental expenses of the same.

On motion of Mr. Whitney, the thanks of the Society were voted to the Edison Electric Illuminating Company, to Mr. C. L. Edgar and to Mr. W. H. Atkins for courtesy extended to the members of the Society on the occasion of the visit to the several stations of that company this afternoon, and for their generosity in providing transportation.

On motion of Professor Allen, the thanks of the Society were also voted to Mr. B. C. Batcheller for the very interesting description which he gave of the pneumatic postal service in Boston, at the informal meeting of the Society on January 5, 1898.

Mr. Frederick H. Newell, chief hydrographer, United States Geological Survey, was then introduced, and gave a most interesting talk, illus-

trated by lantern slides, on the hydrographic investigations of the Geological Survey.

With reference to the methods pursued in the investigation of questions of water supply, Mr. Newell said that in the eastern part of the United States the development of water-powers has in the past been retarded by the fact that transportation lines and centers of population have grown up on the lowlands, away from the cataracts or waterfalls, and it has been found cheaper to utilize steam-power. With the improvement of methods of electrical transmission, it has resulted that the waterfalls can in effect he brought down to the cities, and thus many sources of power are being utilized which before have been regarded as valueless.

In considering the advisability of installing power plants, investors and engineers must first know the volume of the stream and the duration of floods and low water. This matter can be inferred only from the past history of the stream, and such knowledge must be had through accurate records.

In the western part of the United States is the great area of public land, much of it fertile but unproductive on account of the scarcity of water. All land values must be said to rest directly upon questions of water supply. The vacant public domain is in extent equal to one-third of the whole United States, exclusive of Alaska. Little, if any, of this land can be used for farms without irrigation, but with an ample supply of water the farmers are among the most prosperous of the world. The question of the utilization of vast tracts of land is dependent directly upon the quantity and quality of the water and the practicability of putting this upon the surface. Measurements of streams, therefore, are of broad public importance, since they are fundamental to the control and disposition of the homes for future citizens.

In all parts of the United States water for domestic, and even for municipal supplies, is obtained from under ground. In some places the waters near the surface are contaminated, and as a result malarial fevers or other forms of sickness prevail. It is often possible by going deeper to secure a better supply, but through ignorance of this individuals and communities suffer incalculable loss. To be able to place the facts clearly before the people, systematic investigations of the geologic structure must be made.

Incidental to the discussions of the quantity and quality of water in the rivers, and also beneath the surface, are matters concerning the artificial pollution. Towns and manufacturing establishments habitually discharge their sewage and refuse into the rivers, and these flowing, perhaps, across State boundaries are used in turn as sources of supply. The effect is seen in the death rate, but being a matter of common occurrence the importance of taking remedial steps is not kept before the citizens. It is practicable in many places to use this waste material, and, in any event, it is cheaper to do so than to allow it to add to the expenses of the community through sickness and shortening of life.

The investigation of the water resources of the country results in the accumulation of a large amount of data having practical application along many lines beside those above enumerated. The facts are published in annual reports, and in pamphlets entitled "Water-Supply and Irrigation Papers." In a work as widespread as this, it is, of course, impracticable to take up everything at once, and therefore attention is given the typical

localities or conditions. Streams which illustrate general conditions are measured, and underground structure is studied in localities where the results will have first importance.

An attempt is made to carry on field work in all sections of the United States from New England to California, but due care is taken that this wide diffusion does not lead to wasted effort. The methods of work, especially those of measuring streams, have been developed through many years of experience, special instruments being devised from time to time. The data resulting is of especial interest to engineers, since it is through their plans and estimates that construction of necessary works for development or improvement can be made.

At the conclusion of the lecture the thanks of the Society were voted to Mr. Newell for his interesting and instructive paper. Adjourned.

S. E. Tinkham, *Secretary.*

ASSOCIATION OF ENGINEERING SOCIETIES.

VOL. XX. FEBRUARY, 1898. NO. 2.

PROCEEDINGS.

The Civil Engineers' Club of Cleveland.

CLEVELAND, FEBRUARY 8, 1898.—The regular meeting was held in the room of the Club in Case Library, on Tuesday, February 8, at 7.45 P.M.; with President Ritchie in the chair. Present, thirty-eight members and two visitors.

The minutes of the previous meeting were read and approved.

The application of John Frederick Corlett for admission as associate member was read and referred to letter ballot.

The Executive Board reported the cases of those who have been elected to membership at different times and have failed to qualify as members or to pay any fees or dues. The names and dates of election are as follows: Isaac K. Pierson, elected active member, March 13, 1894; Philip E. Knowlton, elected active member, March 9, 1897; Wm. Oehlstrom, elected associate member, March 9, 1897; Wm. C. Thayer, elected associate member, January 12, 1897; Arthur McAllister, elected associate member, May 11, 1897; Lord M. Coe, elected active member, July 13, 1897; Ernest W. Hulet, elected active member, July 13, 1897. The board reported that it had declared the election of these parties void, as provided in Section 9 of Article III of the Constitution.

The resignations of Prof. Frank M. Comstock and Mr. L. E. Holden were reported as having been accepted by the board.

A memorandum from Chas. Orr, librarian of Case Library, was submitted, dated January 19, 1898, showing that there are now in that library about 700 volumes on engineering subjects belonging to Case Library and about 300 volumes belonging to the Civil Engineers' Club; and of the periodicals in the library, 61 belong to Case Library and 18 to the Civil Engineers' Club, these periodicals each embracing a greater or less number of volumes not specified.

Messrs. J. L. Culley and James McIntyre were appointed tellers to canvass the ballots cast upon the amendments to the Constitution, and also for the election of Henry Williams Guthrie as associate member. Upon receiving the report of the tellers, the President announced the adoption of the proposed amendments to Articles III-IX, inclusive, the same being all the amendments proposed. The President also announced the election of Henry Williams Guthrie as associate member.

The report of the Committee on New Quarters was presented and read by the Secretary. Mr. W. R. Warner moved the adoption of the report, which was seconded by Mr. Parmley. Mr. Ambrose Swasey argued in favor of the report as presenting a feasible plan and offering an opportunity to the Club of acquiring a splendid house. Dr. C. S. Howe followed with the same line of argument, and showed that by paying $5 extra per year the membership would enjoy a privilege which costs $50 a year in any other club. He moved that the report be discussed section by section, but withdrew his motion in favor of a motion by Mr. C. G. Force, Jr., who moved, as a substitute to Mr. Warner's motion, that the report be received and printed. Mr. Warner withdrew his original motion, and the motion of Mr. Force was carried. Mr. Force moved that the report, when printed, be made the subject of a special meeting to be called by the President. Seconded and carried.

The Nominating Committee reported a ticket for the coming year as follows: For President, Frank C. Osborn; for Vice-President, S. T. Wellman; for Secretary, Wm. H. Searles; for Librarian, Wm. E. Reed; for First Director, Joseph R. Oldham; for Second Director, S. T. Dodd; for Third Director, R. A. Harman; for Fourth Director, C. W. Hopkinson. On motion, the report of the committee was adopted. On receiving the report from the committee, the Secretary called attention to the fact that it was defective in not naming a Treasurer, and moved that the report be returned to the committee with leave to correct instanter. The report as corrected bore the name of Walter Miller for Treasurer.

Mr. Walter C. Parmley then read the paper of the evening, entitled "Rainfall and Run-off in Relation to Sewerage Problems." It was an elaborate discussion of the theory of sewer discharge, combined with many practical suggestions from actual experience. He exhibited a number of charts indicating the character, intensity and duration of storms as recorded in different parts of the country, showing that those of greatest maximum for short periods may not always tax the sewers so much as others of a more steady downfall.

He showed the importance of considering the direction of the flow in sewers in relation to the direction of the movement of prevailing storms. Where the directions coincide the sewers are more heavily taxed than in other cases. He suggested some new mathematical expressions for the time required for storm water to pass through a sewer of varying diameters. He proposed to increase the exponent of the area A in the formula for discharge of sewers from 4-5, as commonly used, to 5-6, which gives a relatively larger discharge for large drainage areas, while giving about the same results for small areas; and agrees better with the experience in the city of Cleveland.

The paper was discussed by Messrs. M. E. Rawson and C. G. Force, Jr., members of the Club.

Mr. Swasey presented to the Club two large framed photographs of the Forth Bridge of Scotland. One of these, showing the bridge in course of construction, is now exceedingly rare and valuable. Mr. Swasey remarked on the impressively large dimensions of this bridge, the three main cantilevers aggregating a length of 5300 feet, the posts of the steel towers being 12 feet in diameter and 300 feet high above the masonry. On his late visit to the bridge he found fifty men engaged in painting it, and was informed that it would require three years for them to finish the job, and that it

would consume 150 tons of paint. The hearty thanks of the Club was extended Mr. Swasey for his valuable gift.

Dr. Howe moved that a banquet committee of seven members be appointed by the President. Carried. After adjournment luncheon was served.

Wm. H. Searles, *Secretary.*

Cleveland, February 22, 1898.—The semi-monthly meeting was held in the room of the Club, in Case Library, on Tuesday, February 22, at 7.45 p.m., President Ritchie in the chair. Present, twenty-five members and four visitors.

The minutes of the last meeting were read and approved. The President announced that he had appointed as a Banquet Committee Dr. Chas. S. Howe, Jos. C. Beardsley, John P. Johnston, Jos. R. Oldham, Frank C. Osborn, John N. Richardson and James C. Wallace. As Dr. Howe had been unable to serve on this committee the President had appointed Mr. Wm. L. Otis in his stead. The committee had elected Mr. Beardsley as its chairman. The President announced the business of the meeting to be consideration of the report of the Committee on New Quarters, and requested the Secretary to read the report.

After the reading of the report Mr. A. H. Porter moved its adoption. This was seconded by Mr. Osborn.

Mr. A. L. Hyde moved as an amendment that the report be referred to letter ballot in order to obtain a larger vote on the question than could be had in the meeting. This was seconded by Mr. C. O. Palmer.

Mr. Searles suggested that this meeting had been called for the discussion of this report, and a free interchange of views, which could not be had by letter ballot. Even if this question were referred to letter ballot, it would be desirable to discuss it first. The Secretary then read two letters bearing on the subject. These were from Mr. C. M. Barber and Mr. N. P. Bowler, who argued in favor of the project, and also a letter from Mr. J. L. Culley, who expressed himself as opposed to it.

Mr. J. P. Johnston questioned whether the revenue from the house as estimated in the report could be realized.

Mr. J. L. Gobeille was in favor of deciding the question in the meeting. In all such enterprises, he said, a very few people decide If they take the lead, the masses will follow. There are able men in the Club who would be glad to aid it in this manner if the opportunity were afforded them. The revenues of the house are assured, and the idea of bankrupting the Club is absurd. We know the gentlemen who want these bachelors' quarters. He referred to the remarkable success of other clubs lately established in Cleveland. The men composing this committee are not men who sign to fail.

Mr. F. C. Osborn supported the views just expressed and thought that now was the time to act in this enterprise.

Prof. J. W. Langley expressed himself as not being decidedly on either side, but feared that the increase of dues might bar young men from joining the Club. The Club needs money, but also the co-operation of all its members, and particularly of those who read papers and take part in discussions. for this is the real life of the Club. It is largely the working men of the Club who have contributed papers. He was inclined a year ago to take a rosy view of this project, but at present he did not feel so hopeful.

Dr. D. C. Miller concurred with the views of Professor Langley, and thought that the increase in dues would not bring corresponding benefits to the members. We all appreciate the advantages of a Club House, but those who would be the most benefited by a Club House belong to other clubs which can furnish them greater values than ours. He feared that the increase in dues might cripple the Club, and cause many resignations. The enthusiasm of the committee was certainly encouraging to him, and he only referred to the increase of dues as affecting the more active members who are less able to stand the cost.

Mr. Gobielle replied to this by saying that men who could write valuable papers and could not afford to pay a few dollars more to see those papers go all over the country, knew very little about advertising, and those who drop out doubtless spend more for beer and tobacco many times over than the extra dues would come to.

Mr. Searles thought the question was, would not a member get far more for his $15.00 in a house which belonged to the Club, in which the Club could gather its valuables, and such contributions as the public would be glad to make to its library, were the Club prepared to take care of them, than for $10.00 in this bare room behind this curtain? He quoted from Dr. Howe, who said at the last meeting that a member in this Club, by paying $15, would enjoy privileges that would cost him $50 in any other club in town.

If the Club should adopt the report of the committee it would simply signify its willingness to try the plan. The next step would be to get the individual subscriptions to the stock, and if the subscriptions are realized, then the enterprise could go right along. The present scheme was thought to be adapted to the wants of the Club, and he believed the money could be raised. If this plan were not adopted, what would the Club do? Would it remain in this place for the next ten years as it has for the last ten?

Mr. Porter thought the present scheme was a little ahead of the times. We certainly need a Club House badly enough, but is not this experiment on too large a scale? He felt some local pride, and would be pleased to have the Cleveland Club own its own Club House, and hoped we could keep this thing moving, so that in time we could succeed. He thought that if all took hold it could be carried through.

Professor Skeels remarked that there seemed to be some question about being able to keep up expenses. Could this agreement be made in such a way that the Club would not lose anything, but could merely take a longer time to finish the payment if it became necessary to do so?

The President remarked that the company to be formed, being composed of members of the Club, would be willing to allow the Club to have an extension of time if there was any difficulty in meeting the payments.

Mr. Hyde said in support of the amendment that in a matter of such importance we must have the Club behind us, and thought that every member should be given an opportunity to vote. He was heartily in favor of the scheme.

Mr. L. B. Hoit said there were two distinct questions—first, the increase of dues, and second, the indebtedness which the Club can assume. These points should be considered separately, for members might vote only on the question of dues, without regarding the question of indebtedness.

Mr. C. O. Palmer argued in favor of letter ballot, and thought we

should obtain a much fuller vote on this question than we ordinarily do in the election of members.

Mr. J. N. Richardson was opposed to referring the question to letter ballot. Those who vote by letter ballot would have had no opportunity to hear discussion, and would necessarily have very imperfect views of the merits of the case.

The question on the amendment was then demanded. The result of the first vote being uncertain, the President called for a rising vote and declared that the amendment was lost.

The question on the adoption of the report was then put to vote and carried.

The Chairman of the committee presented and read a prospectus for the formation of the Library Company, and also a form of agreement to be signed by members of the Club pledging themselves to support the increase in dues as a part of the general plan, in case the company is formed. These were discussed, but not acted upon.

Mr. Johnston moved that the present committee be continued and be requested to see what can be done towards raising the necessary amount. This was seconded and adopted unanimously.

The Club then adjourned for luncheon at 9.30 P.M.

WM. H. SEARLES, *Secretary.*

Engineers' Club of St. Louis.

462D MEETING, DECEMBER 1, 1897.—The meeting was called to order at 8 P.M., at 1600 Lucas Place; with Vice-President Bryan in the chair. Thirty-nine members and eight visitors were present.

The minutes of the 461st regular meeting and the 246th meeting of the Executive Committee were read and approved.

The Secretary announced that applications for membership had been received from Hiram Martin Chittenden, officer of the Corps of Engineers, U. S. A., and from John Broome Guinn, engineer for the United States and British Columbia Mining Company. These applications were referred to the Executive Committee.

The Committee on Nominations, by its chairman, Mr. B. L. Crosby, reported the following nominations for 1898:

For President—Wm. H. Bryan.

For Vice-President—B. H. Colby.

For Secretary—Richard McCulloch.

For Treasurer—Thos. B. McMath.

For Librarian—E. J. Jolley.

For Directors—Edward Flad and F. B. Maltby.

For members of the Board of Managers of the Association of Engineering Societies—J. B. Johnson and Arthur Thatcher.

When this report had been read, additional nominations were called for, and E. A. Hermann was nominated for Treasurer, and John A. Laird for Director.

The Secretary then read his annual report, and also read that of the Treasurer. The report of the Treasurer was referred to the Executive Committee for auditing. Mr. Wm. H. Bryan, the Acting Librarian, made a verbal report of the condition of the library. Prof. J. B. Johnson, member of

the Board of Managers of the Association of Engineering Societies, made a verbal report.

A motion was made and carried that the customary annual dinner be held on December 15.

Mr. B. L. Crosby made a motion to change Section 3 of Article 2 of the Constitution in regard to the manner of electing honorary members. This motion called forth considerable discussion and several amendments were made to the original motion. Action on this motion was postponed, to be taken up later in the evening.

A motion was made and carried that the vote on the nomination of Prof. Calvin M. Woodward as honorary member be postponed.

The paper of the evening, by Prof. Malverd A. Howe, entitled "Arches," was then read. A history of the stone arch was given with a description of the arches found in the ruins of the ancient cities. The stone arch was traced down to modern times, and stereopticon views of the famous arches were shown. A number of views of noted bridges in stone and steel were exhibited, and interesting data concerning them was given.

At the conclusion of the paper, Prof. J. B. Johnson moved that a vote of thanks be extended to Prof. Howe for his paper. The motion was carried.

Mr. Crosby's amendment to the Constitution was then taken up. The motion as amended was as follows: "That Section 3 of Article 2 of the Constitution be amended to read as follows: 'Honorary members shall be persons eminent in engineering or mechanical science, and shall be elected upon the recommendation of the Executive Committee, by letter ballot, which shall be sent to the members at the same time as the ballot for the annual election of officers. Ninety-five per cent. of the votes cast for the candidate must be in his favor to insure election. Honorary members shall be entitled to all the privileges of members, excepting the right to vote and hold office, and shall be subject to no fees or assessments of any kind.'"

This motion upon being put to a vote was carried by two-thirds majority.

There being no further business, the meeting adjourned to another room, where lunch was served.

Richard McCulloch, *Secretary.*

467th Meeting, February 16, 1898.—The meeting was held at 1600 Lucas Place at 8 p.m.; with President Bryan in the chair. Thirty-four members and twenty-nine visitors were present, seventeen of the visitors being ladies. The minutes of the 466th regular meeting and the 252d and 253d meetings of the Executive Committee were read and approved.

The application for membership of Mr. Elliott Jones having been favorably approved by the Executive Committee, this gentleman was balloted for and elected a member of the Club.

The Secretary announced that he had received an application for membership from Mr. William Anderson Caldwell, Jr., of the Engineering Department of the Bell Telephone Company.

The President announced the appointment of the following Entertainment Committee: Prof. J. H. Kinealey, Chairman, and Messrs. W. A. Layman, E. R. Fish, George Bouton and Henry Branch.

The paper of the evening, entitled "Recent Advances in Electric Railway Practice," by Mr. Richard McCulloch, was then read. The paper de-

scribed the recent applications of electricity to interurban roads and heavy railroad service. A general description was given of the conduit roads now being installed in New York City. About sixty stereopticon views illustrating the paper were shown. After the reading of the paper the meeting adjourned to the library, where refreshments were served and an informal reception held.

RICHARD McCULLOCH, *Secretary.*

Technical Society of the Pacific Coast.

SAN FRANCISCO, CAL., DECEMBER 3, 1897.—Regular meeting called to order at 8.30 P.M., by President Molera.

The minutes of the last regular meeting were read and approved.

Professor Frank Soulé read a paper on the subject of "The Holding Power of Nails in Redwood and Oregon Pine Timbers," which was discussed by Messrs, Percy, Henny, Storey and others. Professor Wing read a series of interesting results of Watertown Arsenal tests of Oregon pine columns.

The following Nominating Committee was appointed to prepare a ticket naming the officers for the ensuing year: Luther Wagoner, C. E. Grunsky, H. C. Behr, Professor Soulé, Adolf Lietz.

The President called attention to a contemplated entertainment to be given by the members of the Technical Society, in the way of a musical evening, such as was had during the past summer, and which proved a success. The members present thought that such an entertainment would bring them together socially, and were in favor of it.

The President thereupon appointed the following committee, acting with full power, to complete any suitable arrangement for the purpose: Hermann Barth, C. E. Grunsky, D. C. Henny, Adolf Lietz and E. J. Schild. The President and Secretary to be ex-officio members of this committee.

Adjourned.

OTTO VON GELDERN, *Secretary.*

FEBRUARY 4, 1898.—Regular meeting called to order at 8.30 P.M. by Vice-President Percy.

The minutes of the last regular meeting were read and approved.

The following applications were made: For member, Waldemar Younger, of Vladivostock, Russia; proposed by R. L. Dunn, D. C. Henny and Otto von Geldern. For associate member, Newton M. Bell, of San Francisco, Cal.; proposed by Luther Wagoner, C. E. Grunsky and Hermann Barth.

A paper prepared by W. W. Waggoner, of Nevada City, entitled "The Flow of Water with Uniform Motion," was read and discussed. The paper was referred to the Executive Committee for further action.

The death was announced of Randell Hunt, civil engineer, member of this Society.

It was moved by Professor Soulé that a committee of three be appointed, including the chairman, to draw up suitable resolutions in memory of the deceased member. Carried.

The Chair appointed on this committee C. E. Grunsky and Otto von Geldern. Adjourned.

OTTO VON GELDERN, *Secretary.*

Civil Engineers' Society of St. Paul.

St. Paul, Minn., December 6, 1897.—A regular meeting of the Civil Engineers' Society of St. Paul was held at 8.15 p.m. Present twelve members, Vice-President Crosby presiding. Minutes of previous meeting read and approved.

A letter of Representative Woodman concerning the Association of Engineering Societies was read, and the matter therein to be considered was laid over to the next meeting.

Two proposed amendments to the Constitution were discussed. Amendment to Article 3 was put on its preliminary passage and carried. Amendment to Article 1, proposing a change of name, failed to pass on its first reading.

Mr. Powell suggested that a committee be named to confer with the City Charter Commission in regard to the office of City Engineer, and the following committee was appointed, on motion of Mr. Estabrook: Mr. Woodman, Mr. Powell, Mr. Crosby and Mr. Loweth.

C. L. Annan, *Secretary.*

St. Paul, Minn., February 7, 1897.—A regular meeting of the Civil Engineers' Society of St. Paul was held at 8 p.m. Present ten members. President Estabrook in the chair. Minutes of previous meeting read and approved. The discussion of a program for the current year resulted in continuing with the President the responsibility of providing matter for each evening's consideration.

The President read an illustrated paper on "Mining Pennsylvania Anthracite Coal Thirty Years Ago." Most of the members present had a word or two to say in regard to the various Western coals.

Adjourned at 10 p.m.

C. L. Annan, *Secretary.*

The Detroit Engineering Society.

Detroit, Mich., February 18, 1898.—The regular monthly meeting was held at the Hotel Ste. Claire, President Jesse M. Smith presiding, and twenty-two members and seven visitors present.

The applications of Messrs. M. Woolsey Campau and Andrew H. Green, Jr., being reported upon favorably they were elected to resident membership.

The paper of the evening, entitled "A Design for Permanent Track," by Mr. J. W. Schaub, member American Society Civil Engineers, was read by the Secretary and produced an extended discussion, participated in by Messrs. Smith, Torrey, Dunlap, Douglas, Molitor, Williams, Goldmark, Robinson, Russell and Dow.

The thanks of the Society were extended by the President to the author and to Mr. George H. Fenkell for the preparation of a diagram in illustration of the paper.

Adjourned.

Gardner S. Williams, *Secretary.*

Meeting of Executive Committee at Room 36 Moffatt Block, February 18, 1898. Present Messrs. Smith, Dow, Keep and Williams. The applications of Messrs. Campau and Green for resident membership were indorsed, and bills for printing, $2.50, and for the Journal, $72.75, were ordered paid.

Adjourned.

Gardner S. Williams, *Secretary.*

Montana Society of Engineers.

The regular monthly meeting of the Society was held February 12, 1898, in the Society's rooms, in Merchant's National Bank Building, Helena, Montana. The meeting was called to order at 8 p.m. by Vice-President F. J. Smith.

The other members present were Messrs. James H. Kerr, James S. Keerl, F. J. Taylor, Finlay McRae, John W. Wade, T. M. Ripley and A. S. Hovey.

The following applications for membership were favorably considered and will be voted upon by letter ballot:

H. P. Clark, of Winston; E. I. Cantine, Helena; W. S. Fortiner, Hamilton; and the following of Butte: R. D. Grant, D. E. Heller, John MacGinness, C. W. Clark, B. H. Dunshee, C. F. Booth, R. T. White, J. K. Clark, A. J. Schumacher, C. H. Hand, August Christian, Samuel Barker, Jr., Max. Hebgen, H. W. Turner, William E. Donovan. Classified professionally, 7 are managers and superintendents of mines, 4 mining engineers, 2 civil and mining engineers, 2 civil engineers, 2 electrical engineers and 1 architect.

The report of the trustees was read. They approved the reports of the Secretary and Treasurer; they recommended additional bookcases for the library. A motion was carried to publish the proceedings of the eleventh annual meeting held in Butte.

President Page appointed the following committees: State Engineer and Road Laws—F. W. Blackford, of Butte; John Herron, Marysville; and T. M. Ripley, Helena. The Committee on Papers are Eugene Carroll, of Butte; Finlay McRae, Helena; and E. R. McNeill, Boulder.

The Society was much encouraged by the interest and activity of the Butte members. Some in particular are deserving of special credit. Plans were discussed to increase an interest in the Society and of procuring more papers. If any member offers as an excuse a lack of time, he will immediately be referred to the Past President's closing remarks: "So true it is, that it is not time which is wanting to men, but resolution to turn it to the best advantage."

A. S. Hovey, *Secretary.*

Engineers' Club of Minneapolis, Minn.

Minneapolis, Minn., February 14, 1898.—Annual meeting held at Hotel Hyser at 8 p.m.

Vice-President Irving E. Howe in the chair.

The minutes of the last meeting read and approved.

W. R. Hoag, chairman of the Committee on New Members, reported

that the result of their labors was shown by the ten members elected at the last meeting.

The Secretary then announced the following as proposed for membership: K. Oustad, by I. E. Howe and E. H. Loe; F. D. Walker and Frank Hewett, by W. R. Hoag and G. D. Shepardson; and C. H. Chalmers, by G. D. Shepardson and H. E. Smith.

G. D. Shepardson, of the Board of Managers, reported that it had been decided to discontinue sending duplicate copies of the Journal to members of the board—that if the Club desired, not to exceed five copies per member of board to which they are entitled, the Secretary should notify Mr. Trautwine, and they would be sent to the Club. Also that the board wished all societies to take Journals for their full membership.

The Secretary was directed, by motion, to notify John C. Trautwine, Jr., Secretary, that our Club desires five copies sent to its Secretary for the use of the Club, and that the Secretary place one copy in the Club's library, and one in the Minneapolis Public Library.

The Chair, on motion, appointed G. D. Shepardson, Albert Graber and E. H. Loe a committee to draft and present at the next meeting for adoption an amendment and addition to Article XII of the Constitution, which shall provide for the payment of annual dues to the Club of such amount and in such manner as will enable the Secretary of the Club to place upon the mailing list for the Journal of the Association Engineering Societies the names of all the members in good standing, and provide sufficient funds for the other ordinary expenses of the Club, leaving the laying of assessments only for use on extraordinary occasions.

Secretary and Treasurer's Report.

RECEIPTS.

Balance on hand last report, January 26, 1897		$8 92
Cash—Collected on old accounts		5 00
Cash—Initiation fees seven new members		35 00
Total		$48 92

EXPENDITURES.

For postage, stationery and notices	$10 56	
" refreshments and rooms, Nicollet House, Jan. 10, 1898	35 50	
" room, Hotel Hyser, February 14, 1898	2 00	
		48 06
February 14, 1898, balance on hand		86
Journal, 1897 account:		
Received from 13 members	$39 00	
Expended, paid J. C. Trautwine, Jr., Secretary	33 50	
Balance		$5 50

Association of Engineering Societies.

Vol. XX. MARCH, 1898. No. 3.

PROCEEDINGS.

Technical Society of the Pacific Coast.

Regular Meeting, held March 4, 1898.—Called to order at 8.30 P.M. by President Molera.

The minutes of the last regular meeting were read and approved.

The following elections were made: Member, Waldemar Younger, civil and military engineer, of Vladivostock, Russia; associate, Newton M. Bell, of San Francisco.

The committee appointed to draft suitable resolutions in memory of the late member, Randell Hunt,, civil engineer, presented a written memoir, which was read and, upon motion by Professor Soulé, ordered spread upon the minutes and sent to the Journal of the Association for publication, together with a photograph of the deceased member. A copy of these resolutions and memoir to be sent to the widow.

Owing to the illness of Mr. Louis Falkenau, who was to have introduced the subject of "High Explosives" for discussion, it was ordered that this discussion be postponed for another meeting.

The President, Mr. Molera, thereupon addressed the Society informally on the subject of the "Drainage System and Canal of the City of Mexico," having recently returned from an inspection of this extensive work. His interesting description of the engineering features involved was discussed by members present.

No further business appearing, the meeting adjourned.

Otto von Geldern, *Secretary*.

Randell Hunt.—A Memoir.

By G. W. Percy, C. E. Grunsky and Otto von Geldern, Committee of the Technical Society of the Pacific Coast.

Died January 24, 1898.

Randell Hunt, member Technical Society of the Pacific Coast, was born in New Orleans, October 30, 1856.

He graduated at Yale with degrees in engineering and philosophy. After leaving college, his first practical experience was gained in connection with the New York public parks.

In 1878 he established an office in Dakota, and identified himself thoroughly with the principal engineering works of the then very active and prosperous West. As a specialty, he devoted himself to bridge structures and foundations, and all through his professional career these were the particular branches in which he excelled and with which his name became prominently connected. Until 1883 he remained in Dakota, with the exception of a period in 1879, when he was attached to the Mississippi River Commission as hydraulic engineer in the investigations of that great waterway.

From 1883 until 1888 he was located at St. Paul, Minn., and employed as constructing engineer by the Chicago, Burlington and Northwestern Railway. He had charge of the bridge work, and under his direct supervision the noted Chippewa River Bridge was built.

In 1888 he came to San Francisco and began a general engineering practice in the line of his specialty. A number of the bridges of this State were designed by Randell Hunt and built under his direction. In 1889 he was made the engineering expert of the contracting firm of Antonelle & Doe, and his name became very prominent in the controversy regarding the concrete foundations for the extensive State works on the sea wall at the foot of Market street, in San Francisco; which caused considerable interest at the time, he contending that the system of sinking the wall by means of open floating caissons possessed innumerable advantages over the method of constructing cofferdams for this work. He devised means for an efficient and rapid execution in this direction, and defended his position so ably that he converted the authorities to his ideas. The Harbor Commissioners finally permitted the use of this system, and the work was successfully carried out. The total length of the wall to be constructed aggregated 450 feet; seven caissons were made use of, six of them 70 feet long and one 34 feet. They were sunk in depths of from 10 feet at low water stage to 17 feet at high water. Only one set of sides and ends was used for the six large caissons. The sides and ends were attachable and detachable to and from the grillage forming the bottom of the structure. These designs were very interesting, and all through this extensive work this method of operation gave great satisfaction, for no mishap of any serious consequence occurred.

With our late fellow-member engineering was more than the mere means of making a livelihood. With an inborn love for his profession, he gave to every case before him a careful and deliberate study; and if he advocated his designs and upheld them with all the vigor of his energetic character, it was because he was led by an honest conviction that he contended for that which he knew to be right, and that nothing should influence him to swerve from the path which he had laid out.

His name may be found frequently in the professional literature of recent years. A paper read before the Technical Society of the Pacific Coast, entitled "Cofferdams and Floating Caissons," was published, and found a widespread circulation by frequent reprints in the principal engineering journals of the country. In this paper the merits of the two methods of founding were intelligently discussed. On the subject of foundations, a number of valuable contributions from his pen are extant; a more recent one considered the methods of founding modern high buildings in our large cities, which appeared in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

For years he had carried the idea of publishing an extensive work on the entire subject of foundations, and if he had lived this plan would have been matured. As it was, ill health prevented him from finishing the manuscript, which must now be left to others to arrange and complete.

In 1890 the firm of Doe & Hunt, engineering contractors, was established, and it carried on a successful business for a number of years. Here Mr. Hunt displayed great energy and activity, and the results of his labor are manifest to-day in a great variety of existing public works. His last work under the name of the firm was the very important construction of the headworks and canal of the Turlock Irrigation District. This extensive engineering operation would have been carried to a successful completion by him had it not been for the suspension of all irrigation enterprises, by reason of legal and financial difficulties that threatened disaster to almost every irrigation district in California, the problem of recovery therefrom not having been solved to this day.

In 1897 Mr. Hunt's services were engaged by the commission that had been charged by the Government to decide as to the respective merits of Santa Monica and San Pedro harbors for deep water improvement and shelter to vessels. Here he became the expert in the work of making borings in the two localities, in order to establish the composition of the materials of the respective harbor bottoms. Although then suffering from a malady that proved incurable, and very ill at the time, he carried out this trying work to the end, at a season when the conditions of the weather made it a severe test for a man in health to have been so constantly in attendance as he was.

This indomitable energy, to carry out whatever he had undertaken, was one of the principal characteristics of his nature. Physical indisposition could not incapacitate him. As long as he could be about he performed his full share of the work—and this he did to the very end of his useful life.

Socially he was the most estimable of men. His early training and education had opened his mind to all the ennobling influences of culture and art, and, while he devoted himself to the advancement of his profession, he never lost sight of the many other elements that make up human progress. Classic literature and the literature of the day were known to him as to few others, and he delighted to converse on these subjects with those about him who enjoyed his more intimate acquaintance. He was a most genial companion, alive to every interest, kind-hearted, devoted to his family and friends and always ready to assist others in giving aid and advice.

His father, the Hon. Wm. H. Hunt, was a very prominent man in his day. Under the administration of President Garfield he was Secretary of the Navy; after Garfield's death he was sent to Russia as Ambassador to represent the United States. He died in St. Petersburg in 1885, full of honors and mourned by two great nations.

In Randell Hunt our Society has lost one of its most active and respected members; a loss that we deeply deplore, and one we cannot readily replace. He became a member in 1890, and held a position in the Executive Board for a number of years.

It is therefore most proper to give expression to our feeling and to extend our sympathies to his surviving family. He leaves a wife and two

little girls to mourn his untimely death. He was taken from them in the prime of his years, when a splendid career of usefulness opened up before him. And this seems sad, indeed, that a life so valuable, so pure and noble, should cease when it could least be spared. Our colleague is no more, but he will be remembered by all of us, not only as an engineer of high quality, but as a man of many virtues and broad principles, who had made it the maxim of his life to maintain fearlessly an honest conviction under all circumstances.

He died January 24, 1898, after a lingering illness of several weeks. Members of the Technical Society bore his body to its last resting place and confided it sacredly to the earth.

COMMITTEE.

Civil Engineers' Club of Cleveland.

CLEVELAND, MARCH 8, 1898.—The annual meeting of the Club was called to order at 8 P.M. by President Ritchie in the chair. Present thirty-eight members and four visitors. The minutes of the last meeting were read and approved.

The monthly report of the Executive Board was read.

Messrs. Robert Hoffman and C. O. Palmer were appointed tellers to canvass ballots for members and officers.

The annual report of the Executive Board was read, and on motion accepted and ordered placed on record. Following this were the reports of the Secretary, Treasurer and Librarian, each of which was accepted and ordered placed on record. Mr. Porter made a report for the Program Committee reviewing the technical work of the Club for the year. The report was accepted.

Under the head of correspondence a letter was read from John Walker, of Chicago, and another from Professor Short, of Cleveland, each of which commends the plan adopted for acquiring a Club house. Under the head of miscellaneous business Mr. Mordecai stated that he had received a verbal invitation from Mr. Trowbridge, of the Telephone Company, for the Club to visit the new Central Station some Saturday afternoon. A written invitation is, however, expected, on which the Club may act.

The President called the attention of the Club to the death of George E. Hartnell, who was formerly a member, having been elected in 1887, but discontinued his membership in 1896.

The tellers having made their report in due form the President announced the election of John Frederick Corlott as associate member. He also announced that fifty-seven legal ballots had been cast for the election of officers, and that the entire ticket had been unanimously elected, as follows:

President—Frank C. Osborn.

Vice-President—Samuel T. Wellman.

Secretary—Wm. H. Searles.

Treasurer—Walter Miller.

Librarian—Wm. E. Reed.

Directors to serve one year—Joseph R. Oldham, Samuel T. Dodd.

Directors to serve two years—Ralph A. Harman, Chas. W. Hopkinson.

Those of the newly elected officers present were called upon by name, and short acknowledgments were made by Mr. Searles, Mr. Reed and Mr. Oldham.

Mr. Warner remarked that he missed the individual reports from the members of the Program Committee which were formerly given at annual meetings, and wished they might appear again. Mr. Mordecai seconded the wish. Mr. Porter replied that the Program Committee had discussed the matter, and had voted to leave the report entirely to the chairman.

The Club then listened to an informal address from President Ritchie. He introduced his remarks by saying that the several reports show quite well the state of the Club. They are not very flattering, yet about as usual. The question of the new house is very important and should be sustained. He referred to those who have died during the past year, Royal Gurley and F. A. Coburn, and gave short sketches of their characters. He then referred to certain new enterprises which had been completed near Cleveland during the past year, namely, the Lorain and Cleveland Electric Railway, which is very well built and equipped and is operated at a very high rate of speed, making the distance of 19 miles between Rocky River and Lorain in 28 minutes, including stops. The remainder of his remarks were devoted to a description of the new shipyard at Lorain, built for the Cleveland Ship Building Company. He exhibited tracings of the plan of the yard and dry dock, and of the principal buildings, and described those severally in detail, giving many interesting items.

At the close of his remarks a short discussion followed, in which Mr. Oldham said that in his opinion the shipyard just described was doubtless the most efficient shipyard in the world, and he was familiar with most of them. Many of the old shipyards had grown by gradual enlargements, while this new yard was one complete design. It contained the best appliances, the most modern machinery and most complete arrangement for the construction of steam vessels. Every machine has a direct motor for driving it, and there are 24 motors. The shipyard at Newport News is larger than this, but not so late or complete in design. The largest ship builder in the world had visited the Lorain yard, and had told the speaker it had not its equal. The owners of the yard are thoroughly satisfied with the results attained, and our President is to be congratulated upon the entire success of the undertaking.

Mr. Warner alluded to the suggestion made last year that the Club would be invited at some time to visit this yard, and hoped the excursion might yet be made. The President replied that it was the intention of the company to extend an invitation on the occasion of the first launch, which would probably take place some time in April.

Mr. Mordecai moved that the cordial thanks of the Club be extended to the retiring officers for their services during the past year, which was seconded and received unanimous vote.

Adjourned at 9.45 P.M.

WM. H. SEARLES, *Secretary*.

ANNUAL REPORT OF THE EXECUTIVE BOARD FOR THE YEAR ENDING FEBRUARY 28, 1898.

Presented at the Annual Meeting, March 8, 1898.

The Executive Board in compliance with the Constitution presents its report for the year ending February 28, 1898.

MEMBERSHIP.

On the 1st of March, 1897, the total membership was 181, composed of 142 active, 21 associate, 14 corresponding and 4 honorary members.

During the year 35 candidates have been elected to membership, but as 6 of these failed to qualify the total accessions number 29. Of these 26 are active and 2 associate members, and 1 honorary member.

Twelve active members and 1 corresponding member have resigned, 5 names have been cancelled for non-payment of dues, and two members have been taken from us by the hand of death.

The total loss is therefore 20, leaving a net gain of 9. Two active members have transferred to the corresponding class. As the final result the present membership is 190, composed of 149 active, 22 associate, 14 corresponding and 5 honorary members.

The resident members number 165, and the non-resident 25.

MEETINGS.

The number of meetings held during the past year is 15. The total attendance was 524 members and 86 visitors, an average of 35 members and 6 visitors.

The practice of serving a light luncheon after meeting as a means of increasing mutual acquaintance and sociability has been steadily adhered to. The results are not so marked as had been hoped for, the inconvenience of having to go some distance to a restaurant being quite a different thing from surrounding a table on our own premises. The number of luncheons after meeting was 14 with an average attendance of 32, or 90 per cent. of the average attendance at the meetings. The average cost of the luncheons has been $10.50.

EXECUTIVE BOARD.

The present board has had a very unusual experience in the loss of its members. Of the 7 elected one year ago, 1, our late Secretary is dead, and 2, Mr. Barber and Mr. Jewett, resigned their seats on account of removal from the city. Another being ill for several months reduced the board to a mere quorum. However, the board has held 15 sessions with an average attendance a little less than 5. In future the larger board will probably be less likely to meet with a similar embarrassment.

NEW QUARTERS.

The discussion begun a year ago regarding the purchase of a house for the Club has not as yet reached very practical results, but the interest awakened in the enterprise promises well for its ultimate success. The serious loss of members that the Club sustains from year to year by resignations, and the indifference of many with regard to paying their dues shows that the Club is not offering sufficient inducements or attractions to awaken the enthusiasm and loyalty of its members. While other organizations have pushed forward to a marked success, this Club has been content to pursue the old routine regardless of competition. It would seem to devolve on every member, who has the future success of the Club at heart, to lend his energies and means toward the development of the plans for progress already adopted by the Club.

LIBRARY.

For the state of the library reference is made to the detailed report of the Librarian.

FINANCES.

The reports of the Secretary and Treasurer upon the finances of the Club are appended. The report of the Treasurer has been audited by the Finance Committee, and indorsed as correct.

By order of the Executive Board.

WM. H. SEARLES, *Secretary*.

REPORT OF THE SECRETARY FOR THE YEAR ENDING FEBRUARY 28, 1898:

PERMANENT FUND.

Balance March 5, 1897		$550.85
Receipts from fees, current year	$145.00	
" " " past year	5.00	
" " interest, one year	22 05	172.05
Balance February 28, 1898		$722.90

GENERAL FUND.

Balance March 5, 1897		$365.66
Receipts from dues for 1897-98	$1,477.34	
" " " " past years	118.00	
" " one subscription to JOURNAL	3.10	1,598.44

CREDIT.

Disbursements	$1,803.92	
Balance February 28, 1898	160.18	
	$1,964.10	$1,964.10

LIBRARY FUND.

Balance March 5, 1897		$17.98
Receipts from Library Committee		120.00

CREDIT.

Disbursements for Library account	$114.26	
Balance February 28, 1898	23.72	
	$137.98	$137.98

The disbursements from the General Fund are distributed as follows:

Publications (JOURNAL)	$603.75
Printing	381.95
Stationery	46.07
Postage and express	88.35
Stenographer	37.60
Salaries of clerks	104.20
Memorials for the dead	36.90
Certificates of membership	9.00
Furniture	12.75
Minor expenses	10.30
Case Library memberships	160.00
Rent of room	75.00
Social account	238.05
	$1,803.92

The payments upon the JOURNAL are for five quarters, from the 1st of January, 1897, to the 1st of April, 1898.

The payments for printing include the cost of 300 copies of the constitution and list of members and library catalogue, and $44.50 worth of printing done for the Banquet Committee, which should more properly have been charged to the Social Account.

The amount charged to the Social Account includes the cost of fourteen luncheons after meeting, one luncheon at the water-works tunnel, several bills of engraving for the last banquet and a deficit of $46 in the Banquet Committee's funds.

Altogether, the last banquet cost the treasury $124.13, showing that the price of the tickets was at least one dollar too low, or that greater economy should have been practiced in the expenses incurred. The annual banquet should not be a charge upon the treasury.

There remained uncollected on February 28, 1898, dues to the amount of $378 and the charges on the books of the Club against those whose names have been cancelled for non-payment of dues amount to $149, which may be regarded as an absolute loss.

A stricter insistence by the Executive Board upon the constitutional requirements might have saved the Club a part of this loss. If the Club is to assume the character of a permanent institution in a house of its own, it will be necessary to conduct all its affairs upon a strict business basis. But the better view to take of this matter is to make the Club so important and honorable an institution in the city, offering such advantages and attractions to its members, that each one would regard his obligations to the Club as a debt of honor which it would be his privilege to pay at the earliest opportunity.

All of which is respectfully submitted.

(Signed) WM. H. SEARLES, *Secretary.*

TREASURER'S REPORT, MARCH 9, 1897, TO FEBRUARY 28, 1898:

RECEIPTS.

From ex-Treasurer Wallace, General Fund	$395.66	
" " " Library Fund	17.98	$413.64
From entrance fees		150.00
" A. Lincoln Hyde, Library subscriptions		120.00
" memberships dues		1,565.34
" Subscription to JOURNAL		3.10

DISBURSEMENTS.

Soc. for savings, Permanent Fund	$150.00	
Association JOURNAL	603.75	
Rent	75.00	
Case Library memberships	160.00	
Reporting	37.60	
Library Account	114.26	
Printing, stationery, postage, clerk hire, luncheons and sundries	927.57	
Balance on hand General Fund 160.18		
" " " Library Fund 23.72	183.90	
	$2,252.08	$2,252.08

PERMANENT FUND.

Balance March 9, 1897	$550.85
Deposited since	150.00
Interest credited	22.05
Total	$722.90

(Signed) HIRAM KIMBALL, *Treasurer.*

Audited and approved by Finance Committee.

(Signed) FRANK C. OSBORN,
Chairman Finance Committee.

LIBRARIAN'S REPORT.

During the year 1897 we have received regularly, in addition to various Government, State and city reports, bulletins and pamphlets, the following scientific periodicals: "Proceedings American Society of Civil Engineers," JOURNAL ASSOCIATION OF ENGINEERING SOCIETIES, "Transactions Canadian Society of Civil Engineers," *Cassier's Magazine, Chicago Journal of Commerce, Deutsch-American Technicher Verbandes-Mittheilungen,* "Digest of Physical Tests," "Proceedings Engineers' Club of Philadelphia," "Proceedings Engineers' Society of Western Pennsylvania," *Iron Age, Maschinen Constructeur, Master Steam Fitter, Modern Machinery, Railway Master Mechanic,* "Memoirs Societe des Ingenieurs Civil de France," *Street Railway Review, Western Society of Engineers' Journal.*

We are indebted to the following members for donations mentioned: To Mr. N. P. Bowler for Vols. 3 and 6 of the "American Institute of Mining Engineers;" to Mr. Joseph R. Oldham for a copy of "The Great Lakes Register of Shipping," of which he is the author; to Col. Jared A. Smith for a copy of his "Annual Report for 1896," and to Mr. Ambrose Swasey for two valuable framed photographs of the Forth Bridge.

In the Association of Engineering Societies it is important to note the succession of Prof. G. D. Shepardson, of the University of Wisconsin, to the position so well maintained, as Chairman of the Association, by Mr. S. E. Tinkham, of Boston; also the admission into the Association of the Engineers' Society of Western New York; also the reduction in the assessment for the JOURNAL for the last quarter of 1897 from 75 cents to 25 cents per member.

The total number of papers published in the JOURNAL during the year was forty-seven, and of this number only six were contributed by members of this Club. This showing does not compare favorably with our record for 1896, when we contributed nine papers out of a total of forty-three; but this is partly due to the delay in preparing papers for publication, and a better showing will undoubtedly be made in the next volume. The Program Committee prepared an excellent calendar, and it is to be regretted that the committee was not supported by all the members to whom dates were assigned.

The Library Fund, which was started by Mr. Culley, contained originally the names of forty-two subscribers at $5.00 each, and $210 was paid in. Of the original forty-two, thirty-seven signed for five years, one for two years and four for one year. Three five-year subscribers were

added to the list. As the list now stands, there are forty-five subscribers for the year 1895, and of the $225 due for that year $220 has been paid in. For the year 1896 there are forty-two subscribers, and of the $210 due $150 has been paid to the writer and $5 to the Treasurer. For the year 1897 there are thirty-nine subscribers, and of the $195 due $125 has been paid in. Mr. Fayette Brown has also paid his subscriptions for the years 1898 and 1899. The amount of money received by the writer is as follows: $10 for 1895, $150 for 1896, $125 for 1897, $5 for 1898 and $5 for 1899, a total of $295. Of this amount $120 has been paid to the retiring Treasurer, whose accounts for the year have been closed, and the balance of $175 will be paid to the incoming Treasurer as soon as he assumes office.

Although sixty-four new books have been ordered for the Club, only thirty-two have as yet been placed on the shelves. The others will undoubtedly be received in the near future.

As its part of the agreement, the Case Library has placed seventy books on the shelves during the year.

The list of the "Transactions of the American Society of Civil Engineers" has been made complete. We have all volumes of the *Engineering News* except 1, 2 and 3, and all volumes of the *Engineering Record* except 1 and 2.

An effort should be made to obtain all of the missing volumes of the scientific periodicals in our possession, and a complete card catalogue of the scientific books and other property of the Club should be made at an early day, as the work of preparing such a catalogue will be more laborious the longer it is delayed. It is desirable to have the books on our shelves in proportion to the membership of the different branches of engineering, and an effort in this direction was made in the purchases during the past year. We are a *civil* engineers' club in name only. Some of our best and most active members are mechanical and electrical engineers, and others are chemists and scientists. Though a civil engineer myself, I hope to see in the near future the name of our Club in keeping with its membership, the Engineers' Club of Cleveland.

All of which is respectfully submitted.

(Signed) A. LINCOLN HYDE, *Librarian.*

Engineers' Club of St. Louis.

468TH MEETING, MARCH 2, 1898.—The meeting was held at 1600 Lucas Place at 8 P.M.; with President Bryan in the chair Thirty-one members and eight visitors were present. The minutes of the 467th meeting and the 254th meeting of the Executive Committee were read and approved.

The Secretary announced that he had received applications for membership from Mr. Oliver W. Childs, engineer for the Stupp Bros. Bridge and Iron Co., and from Mr. Leo Charles Dziatzko, engineer with the Mississippi River Commission.

The application for membership of Mr. Wm. Anderson Caldwell, Jr., having been favorably reported upon by the Executive Committee, this gentleman was balloted for and elected a member of the Club.

Prof. J. H. Kinealy as chairman of the Entertainment Committee then made a verbal report. He outlined what the Entertainment Committee wished to do and stated that they had no funds to carry out their purposes.

A motion was made by Mr. Colby that the profits in the publication of 1898 Bulletin be used as an Entertainment Fund. After some discussion this motion was carried.

The paper of the evening by Mr. Wm. H. Bryan, entitled "Recent Improvements in Steam Ferries" was then read. After reviewing the objects of ferries and the different methods which had been used in their operation, the author described a steam ferry boat which has recently been put into operation in this city. The boat is called the "Andrew Christy," and embodies some radical changes in Mississippi River ferry boat construction. The paper was well illustrated by drawings. An informal discussion followed, participated in by Messrs. Ockerson, Flad, Fish, Crosby, McMath, Russell and Kinealy.

There being no further business, the meeting adjourned to another room, where lunch was served.

Richard McCulloch, *Secretary.*

469th Meeting, March 16, 1898.—The meeting was held at the Club's rooms, 1600 Lucas Place, at eight o'clock; with President Bryan in the chair. Twenty-seven members and eleven visitors were present. The minutes of the 468th regular meeting and the 255th meeting of the Executive Committee were read and approved.

An application for membership was announced from Mr. Will Levy, architect.

The Executive Committee having favorably reported upon the applications for membership of Messrs. Oliver W. Childs and Leo Charles Dziatzko, these gentlemen were balloted for and elected members of the Club.

The President read an estimate as to the cost of publishing the 1898 bulletin and the receipts from the advertising.

The paper of the evening, by Mr. E. W. Sterne, was then read. It was entitled "The Steel Frame of the St. Louis Coliseum," and treated of the roof which has lately been built over the Coliseum building in St. Louis. The paper gave a general description of the arches, the loads for which the strains were figured and the grade of steel used in the construction. The details of the various members and the methods by which the expansion was taken care of were described. In the shop work the arch was laid out full size on a laying out floor. The author explained the methods by which the foundations and the hinge pins were accurately located. The paper was illustrated by numerous drawings and lantern slides. The discussion which followed was participated in by Messrs. Ramsey, Johnson, Hermann, Borden, Connor and Crosby.

Professor Johnson presented by title a paper by Mr. Carl G. L. Barth, entitled "Investigation of Columns."

Mr. Crosby called attention to the fact that girders were being taken out of the Polytechnic Building which had been in service about twenty years, and stated that this was a good opportunity to observe the effect of rust upon this class of work.

There being no further business, the meeting adjourned to another room, where lunch was served.

Richard McCulloch, *Secretary.*

Engineers' Society of Western New York.

THE regular meeting of the Society was held March 7, when Prof. R. C. Carpenter, of Cornell University, lectured on "Laboratory Experimental Work at Cornell." The lecture was very interesting, with its accompaniment of stereopticon views showing the laboratory equipment and excellent facilities for scientific research. Among the works of research explained were the experiments concerning the crystallization of iron and the efficiency of chain and chainless wheels. The lecturer emphasized the fact that considerable power was absorbed in tires of different grades, more so than in certain mechanical means of propulsion.

Prior to the lecture, the Librarian was empowered to secure a suitable library case, harmonizing with the appointments of the rooms of the Academy of Natural Sciences, the freedom and use of which has been extended to our Society.

The Secretary was authorized to secure an enlarged portrait of the late Geo. E. Mann, member American Society Civil Engineers, and first President of our Society. The Secretary was further authorized to compile a Year Book at an expense not to exceed $25.

H. J. MARCH, *Secretary.*

Detroit Engineering Society.

DETROIT, MICH., MARCH 25, 1898.—The regular meeting was held at the Hotel Ste. Claire; Vice-President Alex. Dow presiding, with twenty-five members and seven visitors present.

The following papers were read by their authors: "The Ironwork for the Light Guard Armory," by Thos. F. McCrickett, and "Properties of Concrete under Compressive Stresses," by David A. Molitor, and were discussed by Messrs. Greene, Goldmark, McMath, Dow, Bainbridge, Williams, McCrickett and Molitor.

The names of Messrs. Albert E. Greene and Geo. True were proposed for resident membership.

The annual meeting was announced for April.

Adjourned.

GARDNER S. WILLIAMS, *Secretary.*

MEETING of Executive Committee at 232 Jefferson avenue, March 25, 1898. Present Messrs. Dow, Keep, Russel, Pope, Hinchman and Williams. Messrs. Pope and Keep were appointed a committee to audit the Treasurer's accounts.

The Secretary and Treasurer were appointed a Committee on Annual Meeting, and authorized to expend $125, and the President and Secretary were made a Committee on Invitations.

The death of Joseph De Gurse, member of the Society, was announced.

Adjourned.

GARDNER S. WILLIAMS, *Secretary.*

Engineers' Club of Minneapolis.

MINNEAPOLIS, MINN., MARCH 14, 1898.—The regular meeting of the Engineers' Club of Minneapolis, Minn., was held at Hotel Hyser, at 8

o'clock P.M., March 14, 1898; the President, F. W. Cappelen, in the chair. The minutes of the previous meeting were read and approved.

The committee for revising Section XII of the Constitution of the Club reported as follows:

Section XII, as it now stands, reads as follows:

Any person duly elected shall become a member on subscribing his name to the Constitution and paying five dollars to the Secretary. He shall also be liable for the payment of such assessments as shall be voted by the Club. Any member of any other Society in the Association of Engineering Societies, in good standing, may become a member of this Club, when duly elected, without paying the initiation fee, and with a release from annual dues for such period, not over one year, as he may show by certificate he has paid in advance in the Society from which he comes.

It is recommended that the following be inserted after the close of the first sentence:

Each member shall pay annually to the Secretary the sum of five dollars as annual dues, which shall include his subscription to the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

After some discussion, Mr. Redfield made a motion, as an amendment to the Section XII of the Constitution, that the initiation fee of five dollars shall cover all dues of the year in which the members were elected, and that the annual dues for other members be five dollars.

Mr. Howe made a motion to amend Mr. Redfield's amendment, so as to make the dues of new members three dollars for the first year. Amendment lost.

Mr. Redfield's motion was then carried.

Professor Hoag then moved that the report of the committee be accepted. Carried.

The names of those proposed for membership at the last meeting were then read. Mr. Nexsen then moved that the Secretary be instructed to cast the ballot of the Society for the election to membership of Messrs. K. Oustad, C. H. Chalmers, F. B. Walker and Frank Hewett. Carried.

The names of Mr. Morgan Brooks, president of the Electrical Engineering Company, and Mr. J. S. Webster, with the Gugler Electric Company, were presented as suitable persons to become members by G. D. Shepardson and C. L. Pillsbury, and the names of Frank L. Bachelder, James M. Tate and Anthony Zeleny were presented by Professor Hoag and Professor Smith.

The President then read invitations to the Club from the Union Sewer Pipe Company, of Redwing, Minn., and from the Minneapolis Rolling Mill Company, asking the Club to set a time for making a trip of inspection to their respective works. A motion was made that these invitations be accepted. Carried.

It was decided that the visit to the Minneapolis Rolling Mill be made on the evening of March 28, and that the trip to Redwing be taken April 16.

Mr. Irving E. Howe then read an interesting paper on the "Seventh Street Pavement of the City of Minneapolis, Minn."

The second paper of the evening was read by Prof. H. E. Smith, on "Some Effects of Heating and Working upon Iron and Steel." The several points of the paper were illustrated by means of numerous samples.

It was moved and carried that both papers be printed in the JOURNAL of the Association.

After a short social period, the meeting adjourned.

Members present, Messrs. Cappelen, Pillsbury, Howe, Nexsen, Graber, Illstrup, Hoag, Redfield, Stoopes and Smith. Visitors, Messrs. J. H. Gill and H. B. Avery.

H. E. SMITH, *Secretary*.

Montana Society of Engineers.

MEETING HELD MARCH 17, 1898; Vice-President F. J. Smith presiding. There were eight members present. The application for membership by Wm. Trautwine Shaw was favorably considered, and the Secretary directed to send out the usual letter ballots.

There were eighteen elected to membership, as follows: H. P. Clark, of Winston; E. I. Cantine, Helena; W. S. Fortiner, Hamilton, and the following of Butte: R. D. Grant, D. E. Heller, John MacGinness, C. W. Clark, B. C. Dunshee, C. F. Booth, R. T. White, J. K. Clark, A. J. Schumacher, C. H. Hand, August Christian, Samuel Barker, Jr., Max Hebgen, H. W. Turner, Wm E. Donovan. Thirty-nine votes cast, all affirmative.

A vote of thanks was tendered Hon. T. S. Hogan, Secretary of State, for a valuable contribution to the library; also to B. F. Sturtevant Company for a treatise upon "Mechanical Draft," edited by Mr. Walter B. Snow. The Secretary was appointed a committee of one to report upon the necessities of the library in the matter of bookcases, the cost of same and the condition of the treasury. The subject of solar transits was discussed, including the recent invention of J. B. Davis. The Secretary has requested Ulmer & Hoff, of Cleveland, Ohio, the makers of this instrument, to send a descriptive pamphlet of same to each member of the Society.

The Engineers' Society of Western New York requests the following information from the Montana Society of Engineers:

First.—Is there any legislation in your State which requires any special qualifications for the practice of engineering and surveying?

Second.—If so, could you give me any information as to how such legislation was obtained, and a copy of such act, if possible?

Third.—Have you any suggestions to offer in connection with such proceedings?

The next regular meeting of the Society will be held in its rooms in the Merchants' National Bank Building, Helena, Montana, on April 9, 1898, at 8 P.M.

Program for the meeting will be announced at a later date.

A. S. HOVEY, *Secretary*.

OWING to the Montana Society of Engineers being a State organization with its members scattered throughout the State, many of whom receive but little benefit from the library, the Society does not consider it just or advisable to subscribe for periodicals. The periodicals which it receives are through exchange, and are bound and preserved in the library. List of periodicals received: *Engineering Record*, New York, N. Y.; *Railway Master Mechanic*, Chicago, Ill.; *Indian Engineering*, Calcutta, India; *The Irrigation Age*, Chicago, Ill.; *Railway Age*, Chicago, Ill.; *Engineering and*

Mining Journal, New York, N. Y.; *Official Gazette U. S. Patent Office,* Washington, D. C.; *Journal of Association of Engineering Societies,* Philadelphia, Pa.; *Chicago Journal of Commerce,* Chicago, Ill.; *Journal of the Western Society of Engineers,* Chicago, Ill.; Proceedings of Engineers' Club of Philadelphia, Philadelphia, Pa.; *Journal of the Massachusetts Highway Association,* Boston, Mass.; *Modern Machinery,* Chicago, Ill.; *Engineering,* New York; *Journal of National Association of German-American Technologists,* Philadelphia, Pa.; *School of Mines Quarterly,* Columbia University, New York; Transactions of the Liverpool Engineering Society, Liverpool, England; *Railway Review,* Chicago, Ill.; Proceedings and Transactions of the Nova Scotia Institute of Science, Halifax, Nova Scotia; *Travels,* London, England; Bulletins upon Water Supply and Irrigation U. S. Geological Survey, Washington, D. C.; Bulletins Montana Agricultural Experiment Station, Bozeman, Mont.; Bulletins State Agricultural College, Fort Collins, Col.; Bulletins University of Wisconsin, Madison, Wis.; Bulletins Engineers' Club of St. Louis, St. Louis, Mo.; Transactions of the Academy of Science, St. Louis, Mo.; *The Technology Quarterly,* by Massachuetts Institute of Technology, Boston, Mass.; *The Transit,* Engineers' Society, State University of Iowa, Iowa City, Iowa; Publications of Lehigh University, South Bethlehem, Pa.


ASSOCIATION OF ENGINEERING SOCIETIES
Longitude West from Greenwich
CANADA
MEXICO
PACIFIC OCEAN
ATLANTIC OCEAN
GULF OF MEXICO
MONTANA
MINNEAPOLIS
ST. PAUL
DETROIT
BUFFALO
CLEVELAND
BOSTON
Philadelphia
PACIFIC COAST
DENVER
ST LOUIS
VIRGINIA
WASH.
ORE.
IDAHO
MONT.
WYO.
N. DAK.
S. DAK.
MINN.
WIS.
MICH.
IOWA
NEBR.
CAL.
NEV.
UTAH
COLO.
KAN.
MO.
ILL.
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OHIO
W. VA.
VA.
MD.
DEL.
KY.
TENN.
N. C.
ARIZ.
N. MEX.
OKLA.
IND. TY.
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TEX
LA.
MISS.
ALA.
GA.
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N. H.
MASS.
120
105
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75
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25

Association of Engineering Societies.

Vol. XX. APRIL, 1898. No. 4.

PROCEEDINGS.

Boston Society of Civil Engineers.

February 16, 1898.—A regular meeting of the Boston Society of Civil Engineers was held in Chipman Hall, Tremont Temple, Boston, at 7.45 o'clock P.M.; President Dexter Brackett in the chair. Eighty-seven members and visitors present.

The record of the last meeting was read and approved.

Messrs. William W. Cummings and Moses G. Woodward were elected members of the Society.

On motion of Mr. J. P. Snow, the thanks of the Society were voted to Messrs. Walter B. Douglass, Arthur C. Holt and Charles N. Fitts, of the New England Structural Company, for courtesies shown to the members of the Society on the occasion of the visit this afternoon to the shops of that company.

The literary exercises consisted of a series of papers, illustrated by lantern slides, on the "Abolition of Grade Crossings on the Main Line of the Boston and Albany Railroad in Newton." Mr. William Parker described the depression of the tracks, Mr. Irving T. Farnham, the Washington street widening and the various changes in the streets and drains crossing the railroad, and Mr. W. G. S. Chamberlain spoke particularly of the bridge construction in connection with the work.

Adjourned. S. E. Tinkham, *Secretary.*

Annual Meeting, March 16, 1898.—The annual meeting of the Boston Society of Civil Engineers was held in Chipman Hall, Tremont Temple, Boston, at 7.50 o'clock P.M.; President Dexter Brackett in the chair. One hundred and ten members and visitors present.

The record of the last meeting was read and approved.

Messrs. Walter R. Addicks, Edward B. Carney, Christopher Harrison, Joseph R. Hews, Sidney Hosmer, Charles G. Hyde and John W. Link were elected members of the Society, and Messrs. Charles G. Craib and George C. Dunne were elected associates.

The President read the annual report of the Board of Government, and by vote it was accepted.

The Secretary and the Treasurer each presented his annual report, and by vote they were accepted.

The report of the Committee on Weights and Measures was read by its

chairman, Mr. Main, and, after a short discussion by Mr. A. H. Howland, the report was by vote accepted.

The Librarian read the annual report of the Committee on the Library, and by vote it was accepted. It was also voted to appropriate $50 for binding and other library purposes.

On motion of Mr. A. H. French, it was voted, "That the Board of Government be requested to consider and report to the Society upon the expediency of appropriating not exceeding $50 annually for the purpose of supplying the library with standard engineering works."

Mr. Kimball presented and read the report of the Committee on Municipal Civil Service, and by a vote it was accepted.

Mr. FitzGerald, for the Committee on Quarters, made a brief verbal report, which was accepted.

The report of the Committee on Excursions was read by its chairman, Mr. Fletcher, and by vote was accepted.

On motion of Mr. Stearns, it was voted that the question of continuing the several special committees of the Society and the selection of the members thereof, and the question of printing the various reports which have been received this evening, be referred to the Board of Government with full powers.

Mr. Stearns proposed in writing an amendment to By-law 6, by substituting the word "four" for the word "two" in the last line of the first paragraph.

On motion of Mr. Guppy, the thanks of the Society were voted to Mr. Benjamin W. Wells, Superintendent of Streets of Boston; to the management of the Eastern Dredging Company, and to Messrs. Brayman Brothers, for courtesies shown the Society this afternoon.

Messrs. F. I. Winslow and C. W. Sherman, the tellers of the election, submitted the result of the letter-ballot for officers. There being no election for President and Vice-President by letter-ballot, the meeting proceeded to chose from the two candidates having the highest number of letter-ballots.

The President announced, as the result of the balloting, the election of the following officers:

President—Howard A. Carson.

Vice-President (for two years)—Alexis H. French.

Secretary—S. Everett Tinkham.

Treasurer—Edward W. Howe.

Librarian—Frank L. Fales.

Director (for two years)—X. H. Goodnough.

Mr. William E. McClintock then delivered an address on "Roads," which was very fully illustrated by lantern views showing the roads which the Massachusetts Highway Commission have constructed throughout the State.

Adjourned. S. E. Tinkham, *Secretary*.

Annual Report of the Board of Government for the Year 1897-98.

Boston, Mass., March 16, 1898.

To the Members of the Boston Society of Civil Engineers:

In compliance with the provisions of the Constitution, the Board of Government submits its report for the year ending March 16, 1898.

At the annual meeting a year ago the total membership of the Society was 436, of which 427 were members, 5 honorary members and 4 associates.

During the past year we have lost 12 members, 2 by death, 2 by resignation and 8 by forfeiture of membership for non-payment of dues.

There have been added to the Society during the year 37 members. Our present membership consists of 5 honorary members, 3 associates and 453 members; a total of 461.

The record of deaths for the year is as follows: Thomas Doane, died October 22, 1897; William C. Hall, died December 6, 1897.

Ten regular meetings have been held during the year, and the sixteenth annual dinner of the Society was given at the Hotel Brunswick, on March 8, 1898.

The average attendance of members and visitors at the regular meetings was 95; the largest attendance was 127, and the smallest 82. The number present at the annual dinner was 161.

The following papers have been read at the several regular meetings:

March, 1897.—Address of President George F. Swain, "The Status of the Engineer."

April, 1897.—"Construction Work on Abolishing the Grade Crossings in Brockton, Mass.," by J. W. Rollins, Jr. (Illustrated.) "Memoir of Marshall M. Tidd."

May, 1897.—"On the Origin of the Chézy Formula," by Clemens Herschel. "Meteorological Investigations in the Free Air, at the Blue Hill Observatory, Milton, Mass.," by Mr. A. Lawrence Rotch. (Illustrated.)

June, 1897.—"Railroads: Their Development and Methods of Location," by C. Frank Allen. (Illustrated.)

September, 1897.—"Work of the Metropolitan Water Supply of Massachusetts," by F. P. Stearns. (Illustrated.) "Memoir of Horace L. Eaton."

October, 1897.—"The Manufacture and Inspection of Water Pipe," by Thomas H. Wiggin. (Illustrated.)

November, 1897.—"The Strength of Sewer Pipe and the Actual Earth Pressure in the Trench," by F. A. Barbour.

December, 1897.—"The Erection of Metallic Bridges," by F. P. McKibben. (Illustrated.)

January, 1898.—"Hydrographic Investigations of the United States Geological Survey," by Mr. Frederick H. Newell. (Illustrated.)

February, 1898.—"Abolition of Grade Crossings in Newton, Mass.," by William Parker, W. G. S. Chamberlain and I. T. Farnham. (Illustrated.)

The informal meetings of the Society have been continued during the year. The subjects discussed have been as follows:

March 31, 1897.—"Distribution Work of the Metropolitan Water Board," by Dexter Brackett.

April 7, 1897.—"Work in Connection with Metropolitan Sewerage," by William M. Brown, Jr.

April 14, 1897.—"Public Improvement Projects, and Records Relating to Them," by Henry B. Wood.

December 8, 1897.—"Work of the Metropolitan Park Commission," by W. T. Pierce.

December 29, 1897.—"Winchendon Water Works," by F. L. Fuller.

January 5, 1898.—"Pneumatic Postal Service," by Mr. B. C. Batcheller.

January 12, 1898.—"Track Work of the West End Street Railway in the Subway," by A. L. Plimpton.

January 19, 1898.—"Laying Submerged Pipe on the Metropolitan Water Works," by C. M. Saville and W. E. Foss.

February 2, 1898.—"Some Details of Sewer Pipe Construction," by Sidney Smith.

February 9, 1898.—"Some Peculiar Details of the Brockton Sewer Work," by C. R. Felton.

There has been a good attendance at all of the regular monthly meetings, and also at the informal meetings, which have been held in the library room.

We are also glad to note that our well-arranged library and reading room is being more generally used by our members.

We would urge upon the members the desirability of presenting to the Society matter for the informal meetings, for which formal papers requiring preparation are not necessary, but for which talks upon details of every-day work are very acceptable.

The Society has prospered financially during the past year. Our permanent fund has increased $823.63, and the amount of the current fund is $118.42 larger than it was a year ago, notwithstanding the fact that we have paid $224.75 more to the Association of Engineering Societies than during the previous year.

The Board of Government desires to call to the attention of the members of the Society the desirability of recognizing, in a more substantial manner, the services of our Secretary. Since his salary was fixed at $200 per year our membership has nearly doubled, and the additional work connected with the informal meetings largely falls upon his shoulders. That his work is most efficiently done, I think is known to all of our members, and it is the recommendation of the Board of Government that the By-laws of the Society be amended so as to provide that he shall receive an annual salary of $400.

While we are provided with quarters of sufficient size for our present needs, an inspection of the vacant space on the library shelves warns us that it will probably not be many years before we shall again outgrow our accommodations. It is to be hoped that when this occurs we may remove into a building of our own, devoted to the interests of our profession; and with this end in view we trust that other members may follow the example of one who, for each of the past three years, has subscribed $50 toward a building fund.

During the past year the Society has lost, by death, Thomas Doane, one of its oldest and honored members. For nearly ten years Mr. Doane was the President of the Society, and his active interest and wise counsel have been of the greatest value.

On July 3 of the present year will occur the fiftieth anniversary of the organization of this Society, and it is hoped that the event may be observed in a fitting manner.

Respectfully submitted for the Board of Government,

DEXTER BRACKETT, *President.*

Abstract of the Treasurer's and Secretary's Reports for the Year 1897-98.

CURRENT FUND.

Receipts:

Dues from new members	$218.50	
Dues for year 1897-98	3,029.00	
Dues for year 1898-99	13.00	
Rent of rooms	900.00	
Sale of Journals	6.50	
Cash at beginning of year	106.11	$4,273.11

Expenditures:

Rent	$1,650.00	
Association of Engineering Societies	1,475.00	
Printing and postage	347.06	
Secretary's salary	200.00	
Annual dinner	90.50	
Periodicals and binding	40.85	
Incidentals	110.33	
Stereopticon at meetings	94.50	
Reporting meetings	7.50	
Lighting rooms	20.45	
Insurance on library	12.39	4,048.58
Balance on hand		$224.53

PERMANENT FUND.

Receipts:

Thirty-seven entrance fees	$370.00	
Shares of Merchants' Co-operative Bank, retired	1,031.31	
Sale of C., B. and Q. R. R. stock	900.00	
Subscription to Building Fund	50.00	
Interest and dividends	146.86	
Cash at beginning of year	129.55	$2,627.72

Expenditures:

Nine shares Merchants' Co-operative Bank	$572.64	
Dues on shares Merchants' Co-operative Bank	300.00	
Dues on shares Workingmen's Co-operative Bank	300.00	
Dues on shares Volunteer Co-operative Bank	300.00	
Deposit in Boston Five-cent Savings Bank	40.80	
Deposit in Provident Institution for Savings	38.79	1,552.23
Balance on hand		$1,075.49

PROPERTY BELONGING TO THE PERMANENT FUND, MARCH 16, 1898.

One Republican Valley Railroad bond (par value)	$600.00
25 shares Merchants' Co-operative Bank	2,822.03
25 shares Workingmen's Co-operative Bank	925.25
25 shares Volunteer Co-operative Bank	885.50
Deposited in Boston Five-cent Savings Bank	1,050.80

Deposited in Provident Institution for Savings	$1,063.94
Deposited in Old Colony Trust Company	1,075.49
	$8,423.01
Amount belonging to Permanent Fund March 16, 1897	7,599.38
Increase during the year	$823.63

TOTAL PROPERTY OF THE SOCIETY IN THE HANDS OF THE TREASURER.

Permanent Fund	$8,423.01
Current Fund	224.53
	$8,647.54
Total amount March 16, 1897	7,705.49
Total increase during the year	$942.05

Report of Committee on Weights and Measures.

Boston, Mass., March 16, 1898.

To the Boston Society of Civil Engineers:

Gentlemen:—The only official act of any importance which has been enacted during the past year which requires notice in the report of the Committee on Weights and Measures, that your committee is aware of, is the bill passed by both houses of Parliament for the legalization of the metric system. This bill simply abolishes fines which previous to the passage were imposed on its use. It is not a compulsory bill.

In the report of March 17, 1897, of your committee, the history of the bill introduced in the House of Representatives at Washington, by Mr. Hurley, in December, 1895, was traced down to the date of your committee's report. March 19, 1897, at the first or short session of the Fifty-fifth Congress, Mr. Hurley again introduced a bill (H. R. 1058) to fix the standard of weights and measures by the adoption of the metric system. This was referred to the Committee on Coinage, Weights and Measures, in whose hands it is believed still to remain. From a Washington despatch of the 10th of this month, it appears that on that date, "The commission in charge of the reciprocity negotiations of the Government, Representative Hurley, of New York; Prof. O. H. Tittman, of the Coast and Geodetic Survey, and ex-Representative John A. Kasson, appeared before the House Committee on Coinage, Weights and Measures and advocated the adoption of the metric system.

It is to be remembered that the bill previously introduced by Mr. Hurley did not make the use of the metric system compulsory with the people, but simply established it as the legal standard, to which reference should be made in case of dispute or for any other proper purpose.

Various reports have been presented and resolutions passed in this country during the past year regarding the adoption of the metric system, and the one which deserves especial mention, because of its broad nature and influence, is that of the special committee of the National Association of Manufacturers, which was presented at the meeting in New York in January of this year. The membership of this association now numbers upwards of one thousand, representing the leading firms in the different branches of industry.

The committee which presented this report was a particularly strong one, and a few quotations from the report are of interest:

"It has been steadily perfected, and nation after nation has adopted it, until to-day the metric language of quantity is used practically by all the world except two or three nations—the British Empire, United States and Russia.

"Extract from the *Deutsche Export-Zeitung*, Berlin, February, 1897, says:

"'In the whole Russian Empire, beginning with June 1, the metric weights and measures will be used in accordance with a resolution of the last National Russian Congress of Commerce and Industry.' The acting Consul-General of Russia thinks this is probably official and authoritative.

"But the most important view of this whole subject to us is its direct bearing on our trade and commerce. It is the consideration of this point which prompts your committee to urge some action now by this association, looking to the adoption by the United States of the international metric system of weights and measures. In the opinion of your committee no single act of a similar nature would do more for the extension of American trade—would sell more American products at so small a ratio of expense. The adoption of that universal language of quantity would instantly simplify our commercial relations with the following countries."

Then follows in the report a list of countries which have a population of about 423,500,000.

In conclusion this committee of the National Association of Manufacturers submitted a set of resolutions favoring the adoption of the metric system.

A letter from Prof. W. P. Wilson, director of the Philadelphia Commercial Museum, to the association, whose opinion on this subject should have great weight, says:

"It will be a happy and profitable day for the United States of America when it adopts metric weights and measures."

Your committee have ascertained that quite a number of manufacturing concerns in this country are using the metric system in their work in part or whole, particularly those concerns which do an export trade. A partial list showing some of the kinds of business using this system is as follows:

Manufacture of watches and watch tools, injectors, machine tools, measuring instruments, steam engines, ordnance, refrigerating machinery, chemicals and iron works.

The metric system has been adopted in chemistry, metallurgy, assaying, coinage, pharmacy, medicine, optics, electricity, biology and investigations in physical laboratories.

Respectfully submitted,

Chas. T. Main,
Dwight Porter,
Henry B. Wood,
Committee.

Report of Committee on Excursions.

Boston, Mass., March 16, 1898.

To the Members of the Boston Society of Civil Engineers:

The Committee on Excursions herewith respectfully submit the following report:

There have been eleven excursions of the Society during the past year, as follows:

April 21, 1897.—A trip was made to Brockton to see the alteration in the grade crossings of the New York, New Haven and Hartford Railroad; attendance, 75.

May 19, 1897.—A trip was made to the Blue Hill Meteorological Observatory; attendance, 41.

June 16, 1897.—An excursion of the Society, with ladies, was made to the Metropolitan Park Reservation at the Middlesex Fells; attendance, 47.

September 15, 1897.—There was an excursion to Wellesley to view the Covered Reservoir of the Wellesley Water Works; attendance, 26.

September 25, 1897.—A trip was made to the Nashua River System of Metropolitan Water Works, at Clinton, Mass.; there were 140 members and guests present.

October 29, 1897.—A trip was made to the site of the New South Union Station, Boston; attendance, 60.

November 17, 1897.—A trip was made through the Boston Subway; attendance, 134.

December 15, 1897.—A trip was made to visit the new Charlestown Bridge; attendance, 20.

January 26, 1898.—An excursion was made to visit the stations of the Edison Electric Illuminating Company, of Boston; attendance, 65.

February 16, 1898.—A trip was made to the new works of the New England Structural Company, at East Everett; attendance, 20.

March 16, 1898.—A trip was made to visit the large dredge working in Boston Harbor, at the Narrows; attendance, 79.

For the committee,

A. B. Fletcher, *Chairman.*

Report of Committee on Municipal Civil Service.

Boston, Mass., March 16, 1898.

To the Boston Society of Civil Engineers:

Gentlemen:—The Committee on Municipal Civil Service, appointed by the Society, held its first meeting at the rooms of the Society on April 1 last, when arrangements were made for a conference with the Civil Service Commissioners. Your committee met the Civil Service Commissioners at their office on April 13, and discussed with them the subject of examination of persons applying for positions of civil engineers, draughtsmen, etc. As a result of this conference the Commissioners forwarded to the committee a communication from their chief examiner proposing a system for grading the positions and an outline of examination for each grade, and also recommending the appointment of three civil engineers to act as a board of examiners. The committee, after carefully considering the plan recommended by the chief examiner, communicated their views to the Commissioners, suggesting some modifications.

As a matter of interest to the profession, the system of grading as adopted by the Commissioners is given below:

Division A, or Rodmen.—To include chainmen, rodmen and all assistants under whatever designation, except draughtsmen, whose maximum pay does not exceed the rate of $800 per annum.

Division B, or Instrument men.—To include transitmen, levelers and all assistants under whatever designation, except those covered by divisions A and E, and whose maximum pay does not exceed the rate of $1100 per annum.

Division C, or Assistant Engineers (Junior grade).—To include engineers and surveyors in responsible charge of work and engineers in charge of designing, whose maximum pay does not exceed the rate of $1600 per annum.

Division D, or Assistant Engineers.—To include all engineers whose pay exceeds the rate of $1600 per annum.

Division E, or Draughtsmen.—To include all assistants whose duties are chiefly drafting, and whose pay does not exceed the rate of $1300 per annum.

The following is an outline of the examination for rodmen and instrument men, as taken from the fourteenth annual report of the Commissioners:

Rodmen.—Handwriting. Spelling. Arithmetic, including common and decimal fractions, square root, mensuration of surfaces. Algebra, to and including the solution of simultaneous equations of the second degree. Geometry, general properties of plane triangles, simple problems in geometrical construction, mensuration of surfaces and solids. Tracing and lettering. Education and experience. Duties of rodman.

Instrument men.—Handwriting. Spelling. Education and experience. Algebra, to and including the solution of simultaneous equations of the second degree. Geometry, general properties of plane triangles, problems in geometrical construction, mensuration of surfaces and solids. Plane trigonometry, trigonometrical functions, properties of logarithms and use of logarithmic table, solution of triangles, either right or oblique, by either natural functions or logarithms. Duties. Plotting and lettering.

Respectfully submitted,

William Jackson,
George A. Kimball,
Frederic P. Stearns,
George F. Swain,
T. Howard Barnes.

Report of Committee on the Library.

Boston, Mass., March 14, 1898.

To the Boston Society of Civil Engineers:

The Committee on the Library begs leave to present the following report:

During the past year there have been added to the library 178 books and pamphlets, which have been catalogued and placed upon the shelves. Forty-three volumes have been bound by the Society, none of which had been previously accessioned. The total number of accessions is now 3226.

The periodicals which have been kept upon the table for reference have been about the same as last year, and about 40 in number.

The rules adopted in November, 1896, continue to work very well. Sixty-eight volumes have been borrowed by members from the library for home use, and the fines incurred amounted to only 37 cents, which have been turned over to the Treasurer.

The committee begs to recommend the usual appropriation of $50 for the binding of periodicals and pamphlets.

Respectfully submitted,

FRANK L. FALES, *Librarian*,
FRANK P. MCKIBBEN,
CALEB MILLS SAVILLE,
FREDERIC H. FAY.

Engineers' Club of St. Louis.

470TH MEETING, APRIL 6, 1898.—The meeting was held at 1600 Lucas Place, at 8 P.M.; with President Bryan in the chair. Thirty-six members and five visitors were present. The minutes of the 469th regular meeting and the 256th meeting of the Executive Committee were read and approved.

The Secretary announced that he had received applications for membership from Cary Tolcott Hutchinson, consulting electrical engineer, and John Hill, contractor.

The Executive Committee having reported favorably upon the application for membership of Mr. Will Levy, architect, this gentleman was balloted for and elected a member of the Club.

Mr. Robert Moore then gave an informal talk on "Concrete Masonry." He stated that during the past twenty years concrete had to a large extent taken the place of stone work in engineering construction. The reasons were that concrete construction was the cheaper; that small pieces of stone could be used for concrete which would not be suitable for masonry; that high-priced labor was dispensed with, and that the resulting structure is a monolith. He exhibited drawings and photographs of concrete piers, bridges and culverts, and gave data concerning the conditions under which they were built. Messrs. Hermann, Colby, Connor, Flad, Chittenden, Gayler, Holman and Laird then took part in a general discussion concerning the properties and uses of concrete.

There being no further business, the meeting adjourned to another room, where lunch was served.

RICHARD MCCULLOCH, *Secretary.*

471ST MEETING, APRIL 20, 1898.—The meeting was held at 1600 Lucas Place, at 8 P.M.; with President Bryan in the chair. Thirty-three members and ten visitors were present. The minutes of the 470th regular meeting and the 257th meeting of the Executive Committee were read and approved.

The Secretary announced that he had received applications for membership from Mr. Houston Jones and Mr. Charles M. Parker.

The applications of Messrs. Cary T. Hutchinson and John Hill having been favorably reported upon by the Executive Committee, these gentlemen were balloted for and elected members of the Club.

The paper of the evening, by Mr. Fred E. Bausch, was then read. It was entitled "A Modern Telephone Plant." The paper gave a brief summary of the recent progress in telephony, and gave a description of the standard apparatus in use. A discussion was entered into of the modern telephone line with the advantage of copper over iron wire, the effect of capacity on the line, the advantages of cables and the requisites for underground cables. The paper closed with a description of the recent under-

ground conduits installed by the Bell Telephone Company in the city of St. Louis, and the large switchboard built by the same company. A large number of lantern slides illustrating the paper were shown. The discussion which followed was participated in by Messrs. Bryan, Kinealy, Humphrey, Harrington and Crosby.

There being no further business, the meeting adjourned to another room, where lunch was served.

RICHARD McCULLOCH, *Secretary.*

Civil Engineers' Club of Cleveland.

CLEVELAND, APRIL 12, 1898.—The regular meeting was held in the assembly room of the Electricity Building, Case School of Applied Science.

Prior to the meeting the members visited the mechanical and electrical laboratories and inspected the apparatus, and were shown the various processes going on there.

At 8 o'clock the meeting was called to order by President Osborn. Present, forty-one members and sixteen visitors. The minutes of the last meeting were read and approved. The report of the Executive Board was read; also a letter from the Engineers' Society of Western New York, inquiring as to the legal status of the profession in the State of Ohio. The letter had already been officially answered by the Secretary.

Another letter was read from H. M. Wilson, Washington, D. C., suggesting that a memorial be sent to the Ohio Legislature in favor of the proposed topographical survey of the State to be made in conjunction with the United States Geological Survey. An informal discussion followed. Mr. Boalt said the movement was favored by members of the Ohio University, Professor Brown being quite active in the matter. Mr. Warner, Mr. Varney and Mr. Culley discussed the subject, and were of the opinion that the survey was not needed at the present time.

Reports of committees were called for, particularly that of the Program Committee, but no report was made.

WM. H. SEARLES, *Secretary.*

APRIL 26TH, 1898.—The meeting was called to order at eight o'clock by the Secretary. Present, sixteen members and one visitor. The President and Vice-President being absent, Mr. N. P. Bowler was chosen as chairman. The minutes of the last meeting were read and approved.

There being no other business, Captain Lewis J. Germain addressed the Club on the subject of the Des Moines River Improvement, upon which he was engaged in 1856-58. He described the works and their method of construction in detail, and gave interesting accounts of the ingenious manner in which he had overcome various difficulties. He maintained that it is the office of the real engineer to exercise his own genius in contending with emergencies, as well as to follow precedents in the routine of business. By way of illustration, he gave instances from his own experience. He had saved a contractor from loss by showing him how to take out pipe clay at 18 cents a yard, by the use of a special plough drawn by a cable and capstan. He had extemporized a means of ferrying General Lyon's forces over the Osage River in 1861, much to the surprise of the rebels, who had destroyed the old ferry. Other instances were cited. The Captain's

remarks were listened to with attention, and his descriptions were very amusing.

A short discussion followed, and he answered a number of questions. On motion of Mr. Baker, a vote of thanks was tendered Captain Germain, after which the Club adjourned.

WM. H. SEARLES, *Secretary.*

Engineers' Society of Western New York.

THE regular meeting of the Engineers' Society of Western New York was held April 4, 1898, at the Buffalo Library Building. Major T. W. Symons, U. S. Engineer, delivered an interesting lecture on "Coast Defenses and Fortifications," which subject was doubly welcome at this season. An extensive discussion followed, which intensified our respect for the American Eagle, or rather what it symbolizes. Light refreshments were then served at the rooms, and this new departure was joyfully received, if the reader will permit me to so paradoxically express it.

H. J. MARCH, *Secretary.*

Technical Society of the Pacific Coast.

REGULAR MEETING ADJOURNED TO FRIDAY, APRIL 8, 1898.—Held in the hall of the Academy of Sciences, beginning at 8 P.M.

The reading of the minutes was dispensed with by order of the Chair.

Mr. Marsden Manson, member Technical Society, delivered an address entitled "Roadways and Engineering Structures in Europe," illustrated by stereoscopic views, from photographs obtained during his recent European tour as a representative at the last Geological Congress held in St. Petersburg, Russia.

Without attending to further business, the meeting adjourned after the lecture.

OTTO VON GELDERN, *Secretary.*

Civil Engineers' Society of St. Paul.

ST. PAUL, MINN., APRIL 1, 1898.—A regular meeting of the Civil Engineers' Society of St. Paul was held at 8.15 P.M. President Estabrook presided. Present, twelve members and six visitors. Minutes of February meeting read and approved. A communication from Representative Woodman on matters pertaining to the Association of Engineering Societies was read for information of members. Mr. H. E. Stevens, lately returned from the scenes of his subject, gave a two hours' practical talk on ship canals as exemplified in Panama and Nicaragua. There are some drawbacks to the Nicaragua project. No adequate foundations seem to be found for the dams, and a dam on the Ochoa site would necessitate many other embankments of questionable expediency. Furthermore, the physical features of the terminals, especially on the Atlantic, present obstacles very difficult to surmount. As to the estimated cost of this canal, notwithstanding the many surveys, data are still lacking on which to base an intelligent estimate. Inasmuch as one dollar in gold should accomplish nearly as much there as here, the unit prices on which the estimate of the Ludlow

Commission is based, twice the unit prices in the United States, seem to be a little extravagant. In Panama the Chagres problem is rumored to be nearing solution. This is to divert the flood discharge of the river, which is nearly twice as large as that of the Mississippi at St. Paul. The terminal conditions are also favorable on this route; 3500 men are now in the Culebra cut working by primitive and ineffectual methods. The evidences of extravagant waste and gigantic jobbery which marked the conduct of the work in Panama for several years are astounding. A remarkable feature of the clay cuts on both routes is the permanent standing of the quarter to one slopes, unaffected by the torrents of rain, the average monthly precipitation at Greytown being about that of the average year with us.

A vote of thanks was extended to Mr. Stevens.

C. L. Annan, *Secretary.*

Montana Society of Engineers.

A meeting of the Society was held in Helena, on April 12, 1898; Second Vice-President F. J. Smith presiding. Mr. William Trautwine Shaw, of Gilt Edge, Mont., was elected a member of the Society. The application for membership by Mr. F. W. Sherman, Manager of the Gold Mountain Mining Company, at Bernice, Montana, was favorably considered and the Secretary instructed to send out the usual letter ballots. A committee of three, F. L. Sizer, Paul S. A. Bickel and A. E. Cumming, all of Helena, was appointed to consider the question of taking action and co-operating with other states interested in securing a grant of arid lands to be used for the purpose of irrigation developments.

Longitude 105 West from 90 Greenwich
CANADA
PACIFIC OCEAN
ATLANTIC OCEAN
ASSOCIATION OF ENGINEERING SOCIETIES
MONTANA
MINNEAPOLIS
ST. PAUL
DETROIT
BUFFALO
BOSTON
CLEVELAND
Philadelphia
VIRGINIA
ST LOUIS
DENVER
PACIFIC COAST
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IDAHO
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WYO.
N. DAK.
S. DAK.
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Association of Engineering Societies.

Vol. XX. **May, 1898.** No. 5.

PROCEEDINGS.

Detroit Engineering Society.

Meeting of the Executive Committee held at Room 36, Moffatt Block, April 20, 1898. Present, Messrs. Smith, Dow, Russel, Hinchman and Williams.

The applications for membership of Messrs. Albert E. Greene and George True were passed upon favorably.

The resignation of Mr. J. A. Svensson was accepted.

A communication from the chairman of the Board of Managers of the Association of Engineering Societies was read and the Secretary was instructed to reply that the Detroit Engineering Society would defer to the judgment of the older societies in the matter of disposition of advertising receipts, and would favor the continuance of the present practice regarding titles of authors of papers that are published in the Journal.

A communication from the Engineers' Society of Western New York relative to legal enactments affecting the practice of the engineering profession was read and referred to the Secretary for investigation and reply.

It was resolved that in the coming election all nominations be made by informal ballot. The Secretary was instructed to express to Captain William M. Folger, in command of the cruiser "New Orleans," the congratulations and interest of the Society.

A check to T. H. Hinchman, Jr., Treasurer, covering sundry transactions, amounting to $429.07, was ordered drawn.

Adjourned.

Gardner S. Williams, *Secretary.*

The annual meeting was held at the Hotel Ste. Claire, Friday evening, April 29, 1898, President Jesse M. Smith presiding, and thirty-eight members present.

The Executive Committee reported favorably upon the applications of Messrs. Albert E. Greene and George True, and they were elected to resident membership.

The name of Mr. Henry Goldmark was presented for resident membership and referred to the Executive Committee.

The Society then proceeded to the election of officers, which resulted as follows:

President—George Y. Wisner.

First Vice-President—William J. Keep.

Second Vice-President—Alex. Dow.

Secretary—Gardner S. Williams.

Treasurer—Theodore H. Hinchman, Jr.

The members then adjourned to the dining room and participated in the annual banquet, President Smith presiding. The invited guests present were Charles Warren Hunt, Major Milton B. Adams, U. S. A., and E. E. Haskell.

Letters of regret were announced from Col. G. J. Lydecker, Corps of Engineers; Alfred Noble, F. C. Osborn, President of Cleveland Civil Engineers' Club; George S. Davidson, President of Engineers' Society of Western Pennsylvania; F. F. Rogers, President of Michigan Engineering Society; Duncan Kennedy, Commander U. S. N., and Mortimer E. Cooley, Chief Engineer U. S. N.

A letter of regret and greeting was read from Mr. John C. Trautwine, Jr., Secretary of the Association of Engineering Societies.

The Secretary then reported that under the instructions of the Executive Committee he had expressed by letter to our fellow-member, Captain William M. Folger, U. S. N., the congratulations of the Society upon his appointment to command the U. S. Cruiser "New Orleans," and our interest in her future career, and read the following reply:

"U. S. S.'New Orleans,' New York, April 29, 1898.

"Gardner S. Williams, Secretary Detroit Engineering Society.

"*Dear Sir*,—Please convey to the Executive Committee of the Detroit Engineering Society my sincere thanks for their flattering resolution. The 'New Orleans' is a fine vessel, and I have an unusually capable lot of officers. If I have time to get the crew, very green at present, into shape, I do not think the Society will have cause to be ashamed of the 'New Orleans.' Very truly yours,

(Signed) "Wm. M. Folger."

Toasts were proposed and responded to as follows:

"The American Society of Civil Engineers," response by James D. Hawks.

"The American Society of Mechanical Engineers," response by Walter S. Russel.

"The American Institute of Mining Engineers," response by William M. Courtis.

"The American Institute of Electrical Engineers," response by Alex. Dow.

"The United States Engineer Corps," response by Milton B. Adams, Major of Engineers, U. S .A.

"The Michigan Engineering Society," response by Joseph B. Davis.

"The Engineer," response by Charles Warren Hunt, Secretary American Society of Civil Engineers.

"The Engineering Society of the University of Michigan" (by request), response by Gardner S. Williams.

"Our Members in the Michigan Naval Reserve and the Volunteer Navy."

AT THE FRONT.	UNDER AND AWAITING ORDERS.
M. E. Cooley,	W. A. Livingstone,
Gilbert Wilkes,	F. W. Hodges,
T. H. Hinchman, Jr.,	Thomas Farmer, Jr.,
J. F. Lewis,	Andrew H. Green, Jr.,
M. W. Cempau.	Paul E. Fuller.

Response, "The Star Spangled Banner," by orchestra and company. Dismissed.

GARDNER S. WILLIAMS, *Secretary.*

REPORT OF THE SECRETARY FOR 1897-8.

To the President and Executive Committee of the Detroit Engineering Society:

GENTLEMEN:—The following report covers the points of general interest in the history of the Society during the year just closing:

The officers have been: President, Jesse M. Smith; First Vice-President, Alex. Dow; Second Vice-President, Wm. J. Keep; Secretary, Gardner S. Williams; Treasurer, Theodore H. Hinchman, Jr. To these have been added, upon the Executive Committee, Mr. Willard Pope, and as a member of the Board of Managers of the Association of Engineering Societies, Mr. Wm. A. Livingstone.

The membership at the beginning of the year was: Resident, 82; non-resident, 12; total, 94.

Since the last annual report there have been elected to membership 18 candidates, of whom 14 have united with the Society. One member was received by transfer from the St. Louis Engineers' Club, but the transfer was afterwards withdrawn. The Society has lost by resignation 4 members and by death 2 during the past year, and by removal from the city 1.

The present membership is....	Resident,	84	Non-Resident,	17	Total,	101
Dues unpaid..................	"	3	"	4	"	7
Net in full standing...........	"	81	"	13	"	94
Elected and eligible...........	"	3	"		"	3
Candidates proposed..........	"	2			"	2

Meetings of the Society have been held as follows:

April 23, 1897.—Annual meeting and banquet. Present, 36 members; President W. S. Russel presiding.

May 21, 1897.—Regular meeting. Paper, "Characteristics of Modern Yachts and Launches," by F. A. Ballin. Present, 24 members and 2 visitors; Second Vice-President W. J. Keep presiding.

June 18, 1897.—Regular meeting. General discussion, "The Adoption of the Metric System of Weights and Measures." Present, 17 members; First Vice-President Alex. Dow presiding.

July 23, 1897.—Regular meeting. Paper, "Economical Engineering Construction," by Geo. Y. Wisner. Present, 22 members and 2 visitors; First Vice-President Alex. Dow presiding.

September 17, 1897.—Regular meeting. Paper, "The Machinery of the Poe Lock of the Ste. Mary's Falls Canal," by Frank M. Dunlap. Present, 20 members and 5 visitors; Second Vice-President W. J. Keep presiding.

October 22, 1897.—Regular meeting. Paper, "The Manufacture and Use of Aluminum," by Jesse M. Smith. Present, 21 members and 3 visitors; First Vice-President Alex. Dow presiding.

November 19, 1897.—Regular meeting. Paper, "Cast Iron Under

Impact," by W. J. Keep. Present, 32 members and 1 visitor; President Jesse M. Smith presiding.

December 16, 1897.—Regular meeting. Paper, "American Armor for Vessels of War," by W. M. Folger. Present, 35 members and 13 visitors; President Jesse M. Smith presiding.

January 21, 1898.—Regular meeting. Paper, "Decorative Marbles," by W. M. Courtis. Present, 21 members and 7 visitors; President Jesse M. Smith presiding.

February 18, 1898.—Regular meeting. Paper, "A Design for Permanent Track," by J. W. Schaub. Present, 22 members and 7 visitors; President Jesse M. Smith presiding.

March 25, 1898.—Regular meeting. Papers, "The Ironwork of the Light Guard Armory," by Thos. F. McCrickett, and "Properties of Concrete Under Compression Stresses," by D. A. Molitor. Present, 25 members and 7 visitors; First Vice-President Alex. Dow presiding.

The average attendance of members during the year has been 25, and the total attendance 275.

The average number of participants in discussion per meeting has been 8.5, the total number participating being 93.

The books of the Treasurer show the following record for the year:

Receipts:		
Balance from preceding year	$28.98	
Dues and fees for 1897-98	480.50	
Total receipts		$509.48
Expenditures:		
Annual banquet	$101.40	
JOURNAL	235.25	
Printing, postage and exchange	34.47	
Total expenditures		$371.12
Balance on hand		138.36
Dues for 1897-98 unpaid		31.00
Gross assets		$169.36
Bills payable		8.20
Net assets		$161.16

Respectfully submitted,

GARDNER S. WILLIAMS.

DETROIT, MICH., May 20, 1898.—The regular monthly meeting was held at the Hotel Ste. Claire, Friday evening, May 20, 1898, President George Y. Wisner presiding, with twenty members and three visitors present.

After some opening remarks by the President, the Executive Committee reporting favorably, Mr. Henry Goldmark was elected to resident membership. The names of Mr. E. E. Haskell, of Detroit, and Mr. O. L. E. Webber, of Port Huron, were proposed for resident and non-

resident membership, respectively, and referred to the Executive Committee.

The Executive Committee reported the selection of Mr. Willard Pope to complete its membership, and the appointment of Mr. H. G. Field as Deputy Treasurer, to act during the absence of the Treasurer, Mr. T. H. Hinchman, Jr., upon the United States Steamship "Yosemite."

A letter was read from the Secretary of the American Society of Civil Engineers inviting the participation of the Detroit Engineering Society in the events of the Annual Convention, to be held in Detroit, July 26 to 29, inclusive, 1898, and upon motion the Secretary was directed to accept the invitation and to extend the thanks of the Society and express its desire to contribute to the success of the convention.

The paper of the evening, entitled, "Engineering in Connection With the Detroit Water Works," was presented by Mr. Gardner S. Williams and discussed by Messrs. Wisner, Smith, Greene, Russel, Goldmark and Williams. Adjourned.

GARDNER S. WILLIAMS, *Secretary.*

MEETING of the Executive Committee held at the Wayne County Savings Bank Building, May 20, 1898. Present, Messrs. Wisner, Smith, Dow and Williams.

The application of Henry Goldmark was passed upon favorably for resident membership and the resignation of Mr. Chas. F. Adams from resident membership was accepted.

Mr. H. G. Field was appointed Deputy Treasurer to serve during the absence of the Treasurer.

Mr. Willard Pope was selected as a member of the Executive Committee to complete its membership.

Bills to the amount of $128.10 were audited and ordered paid. Adjourned.

G. S. WILLIAMS, *Secretary.*

Memoir of Gouverneur Morris.

Member Am. Soc. C. E. and Detroit Engineering Society.

Gouverneur Morris was born at Pottsville, Pa., November 5, 1847, and died at Detroit, Mich., December 30, 1897. He was elected a member of the Detroit Engineering Society September 17, 1897.

Mr. Morris was a member of the Sons of the American Revolution, and came of an illustrious family, being the grandson of Robert Morris, the famous financier of Revolutionary times and a signer of the Declaration of Independence.

Graduating from the Philadelphia Polytechnic College in 1868, he immediately engaged in civil engineering, and was connected with the Philadelphia and Reading, Chesapeake and Ohio, Northern Pacific and East Tennessee, Virginia and Georgia Railroads, the Pennsylvania Geological Survey and several mining enterprises in Pennsylvania and West Virginia. He was also engineer for O'Brien & Clark on the construction of the Croton Aqueduct, as well as being engaged in several minor engineering undertakings. He was widely known throughout the Eastern and

Southern coal producing States, to whose development in mining he devoted much attention, and at the time of his death was in charge of the coal interests of the Philadelphia and Reading Railroad for Michigan and adjacent territory.

By those of us, all too few, who were enabled, in the brief periods of his sojourn with us, to enjoy his acquaintance, no eulogy can be required. To those who were not so favored we need only say, "he was an engineer."

GEO. Y. WISNER,
GARDNER S. WILLIAMS.

Joseph De Gurse.—A Memoir.

Member Detroit Engineering Society and Canadian Society of Civil Engineers.

Joseph De Gurse was born in the County of Lambton, Moore Township, Ontario, February 26, 1857, and died at Windsor, Ontario, March 22, 1898. He was raised upon a farm, and obtained his education at Assumption College, Sandwich, Ontario, and at the School of Practical Sciences at Toronto. He received his commission as Ontario Land Surveyor in April, 1883, and was engaged in surveying for the Canadian Government in the Algoma and Nipissing districts and the Northwest. In November, 1887, he was appointed chief engineer of the Lake Erie and Detroit River Railway, a position which he held until his death. The road was located and built under his direction. He was also connected with the municipal engineering work of both Windsor and Walkerville, and designed the Ferry Slip Dock at Port Stanley, Ontario. Mr. De Gurse was for many years a member of the Windsor Board of Education, and also chairman of the North Essex Board of License Commissioners. He was elected to membership in the Detroit Engineering Society September 17, 1897.

GARDNER S. WILLIAMS.

Boston Society of Civil Engineers.

APRIL 20, 1898.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, Boston, at 7.45 P. M.; President Howard A. Carson in the chair; sixty-eight members and visitors present.

The records of the annual meeting of March 16, and the special meeting of March 30, were read and approved.

Messrs. M. Irving Motte and Harold C. Stevens were elected members of the Society.

The Board of Government submitted the following report, and on motion it was accepted and adopted:

To the Boston Society of Civil Engineers:

The Board of Government begs leave to present the following report on matters submitted to it by the Society at the annual meeting of March 16, 1898:

It has voted to continue for the ensuing year the Committees on Excursions, on the Library and on Quarters, and has selected the membership of these committees as follows:

On Excursions—Henry S. Adams, Benj. W. Guppy, R. S. Hale, H. F. Bryant and Leonard Metcalf.

On the Library—Frank L. Fales, C. M. Saville, F. P. McKibben, F. H. Fay and A. D. Fuller.

On Quarters—Desmond FitzGerald, E. W. Howe, C. F. Allen, E. W. Bowditch and H. Bissell.

It was voted not to continue the Committees on Weights and Measures and on Municipal Civil Service.

It has appointed the following members to represent the Society on the Board of Managers of the Association of Engineering Societies, in addition to the Secretary: Messrs. J. R. Freeman, Henry Manley, Frederick Brooks and Dexter Brackett.

The board was requested to report upon the expediency of appropriating, not exceeding $50 annually, for the purpose of supplying the library with standard engineering works. The board, after carefully considering the matter, voted that it deems it expedient that the sum of $50 be appropriated this year to be expended for the purchase of standard engineering books, and it recommends that a like sum be expended for this purpose each year when the finances of the Society will warrant.

Respectfully submitted for the Board of Government,

S. E. Tinkham, *Secretary.*

On motion of Professor Allen, the amendment to By-law 6 proposed in writing at the last meeting was adopted by a unanimous vote.

Mr. Brock, for the committee appointed to prepare a memoir of our late associate, William C. Hall, submitted its report, which was read and accepted.

Mr. Henry B. Wood then read the paper of the evening on "Boundaries," giving in some detail the most of the Massachusetts Topographical Survey Commission in connection with the town and State boundary lines.

Adjourned.

S. E. Tinkham, *Secretary.*

William C. Hall.—A Memoir.

By N. S. Brock, B. T. Wheeler, J. L. Woodfall, Committee of the Boston Society of Civil Engineers.

[Read before the Society, April 20, 1898.]

William C. Hall, the son of Nahum B. and Betsey (Wood) Hall, was born in Upton, Massachusetts, on September 27, 1858, and there with his parents he passed the period of his youth and young manhood.

He attended the public schools of his native town, and after exhausting the opportunities for learning which they afforded he entered Dartmouth College. At this institution he took the engineering course in the Chandler Scientific Department, graduating in the class of 1883. He was a bright scholar, being particularly apt in mathematics, as is evidenced by the fact that during an entire year he obtained a perfect mark, both in recitations and examinations, in the higher branches of this study. His lively and genial nature made him a favorite with his mates, and although years have now passed since those days of close companionship, and intercourse has

been in most cases infrequent, his old college associates will still feel in his death the loss of a close and valued friend.

After leaving college he obtained employment in the engineering department of the city of Boston, and on September 2, 1883, was assigned to work in connection with the Main Drainage System. On November 4, 1883, he was transferred to the Department of Additional Water Supply, and on this work, at first in the employ of the city and later in the employ of the Metropolitan Water Board, he served faithfully and efficiently till his death, on December 6, 1897.

During this period he bore a part, gradually increasing in importance, in the preparation and construction of the following works: The Farm Pond Conduit, the lining of Beacon Street Tunnel, the excavation of Pegan Meadows, Dam and Basin No. 6, Dam and Basin No. 5. Of the last-named work, the largest of its kind that has been undertaken by the city of Boston, he was assistant engineer in charge at the time of his death. His work was marked by a high order of excellence, by great zeal and a total disregard of personal comfort.

He joined the Boston Society of Civil Engineers on April 18, 1888, but owing to the fact that his work and home have always been located at a distance from our place of meeting he has not been a frequent attendant.

On October 27, 1886, he married Miss Bertha B. Stewart, of Framingham, and there were born to them four children, three boys and one girl, all of whom survive him.

The sickness and death of Mr. Hall occurred under particularly sad and distressing circumstances. He and his wife were both stricken with the same disease, pneumonia.

Mrs. Hall's attack was from the first a very severe one, and little hope was entertained of her recovery. She died on December 4.

His seizure was thought to be less dangerous, and it was hoped that he might be spared to their young family, which stood now in double need of his watchful care. His heart, however, proved unequal to the extra strain which disease put upon it, and he gradually failed and passed away two days after his wife.

The funeral service of husband and wife was held in Grace Church, South Framingham, on December 8.

Surely all hearts must go out in sorrow and sympathy to this young family, doubly dependent by reason of its youth, and yet doubly bereaved.

As an engineer Mr. Hall was endowed with an unusually happy union of those qualities which give speed and accuracy in performing work,—*i.e.*, he possessed an immense amount of dash and physical energy well controlled and directed by a bright, well modulated mind. He was full, also, of that quality which belongs alike to the good soldier and the good engineer, the cheerful endurance of hardships encountered in the prosecution of his work. He was forceful and determined, quick and correct in judgment, fair and honorable in his dealings with all men. These qualities, joined to a fearless and sunny disposition, made him a leader who inspired his assistants to their utmost endeavors.

He was a true friend, a jolly and agreeable companion. Those of us who were his friends and associates will long remember the sparkle of his bright gray eyes as he attacked us with a volley of that merry banter in the use of which he was so skillful.

In his private life he was an unusually attentive husband and father, devoting every spare hour to the care and entertainment of his children, in whom he took the greatest pride.

Who of us can measure for them their loss.

Engineers' Club of St. Louis.

472D MEETING, May 4, 1898.—The meeting was held at the Club's rooms, 1600 Lucas Place, at 8 P.M.; with President Bryan in the chair. Twenty-two members and seven visitors were present. The minutes of the 471st regular meeting and the 258th meeting of the Executive Committee were read and approved.

The Secretary announced that he had received applications for membership from Messrs. S. B. Fisher, J. S. Branne and J. M. Desloge.

The applications for membership of Messrs. Charles M. Parker and Houston Jones having been favorably reported upon by the Executive Committee, these gentlemen were balloted for and elected members of the Club.

The President stated that he had received an invitation from the Society of Civil Engineers of France to send delegates to its fiftieth anniversary celebration in Paris in June.

The paper by Mr. Thos. D. Miller on "The Recently Discovered Oil Field of Texas" was then read by the Secretary. A description of the oil district of Corsicana, analyses of the oil and statistics regarding the output were given. A sample of the oil and drawings were submitted.

Prof. J. H. Kinealy then gave a talk on the question of ventilation of school buildings. He illustrated his remarks by showing a number of lantern slides. The discussion on ventilation was participated in by Messrs. Bryan, Ittner and Ferguson.

There being no further business, the Club adjourned to another room, where lunch was served.

RICHARD MCCULLOCH, *Secretary*.

473D MEETING, MAY 18, 1898.—The meeting was held at the Club's rooms, 1600 Lucas Place, at 8 P.M.; with President Bryan in the chair. Thirty-eight members and fourteen visitors were present. The minutes of the 472d regular meeting and the 259th meeting of the Executive Committee were read and approved.

The applications for membership of Messrs. John S. Branne, Samuel B. Fisher and John M. Desloge having been favorably reported upon by the Executive Committee, these gentlemen were balloted for and elected members of the Club.

Prof. J. H. Kinealy announced that the Entertainment Committee had arranged for an excursion to Granite City on Saturday afternoon, May 28.

The Secretary announced that the library had been presented with a copy of the third annual report of the Metropolitan Water Board of Boston, Mass.

The President announced that he had appointed as delegates to the convention of the Civil Engineers of France, in Paris, in June, Messrs. Charles Bouton, George W. Olshausen and A. H. Zeller.

Mr. M. L. Holman then made an address upon "The Filtration of Water." He described the present practice in Germany in the filtration of water for the use of towns and cities. A description was given of the open sand filters in use in Hamburg, with the methods of operating and cleaning them. The German Government requires that water for city use shall contain less than 100 bacteria per cubic centimeter, and the water which passes through the filter is tested periodically to see that this requirement is carried out. The covered sand filters in use at Berlin and the artificial stone filters in use at Worms were also described. An interesting discussion followed, participated in by Messrs. Moore, Johnson, Herman, Ockerson, Sanger, Ferguson, Russell, Pitzman, Bryan, McMath, Colby and Dr. Glasgow.

Mr. E. J. Spencer then stated that a bill had passed both houses of Congress and had been signed by the President authorizing the formation of a brigade of engineers, but that this number had been cut down arbitrarily by the Secretary of War to a single regiment to be raised on the Eastern Seaboard. He called attention to the usefulness of engineers in time of war, and suggested that the Engineers' Club of St. Louis take action in this matter by sending a telegram to the Secretary of War protesting against the cutting down of the brigade of engineers. Other members made remarks favoring this action. Prof. J. B. Johnson made a motion that the President appoint a committee of three to act on the lines suggested by Mr. Spencer. This motion was seconded and on being put to a vote was unanimously carried. The President appointed as members of this committee Prof. J. B. Johnson, Lieut. E. J. Spencer and Mr. Julius Pitzman.

There being no further business, the club adjourned to another room, where lunch was served. RICHARD McCULLOCH, *Secretary*.

Technical Society of the Pacific Coast.

MAY 6, 1898.—Regular meeting. Called to order by Vice-President Percy.

The minutes of the last regular meetings of March and April were read and approved.

Mr. Halstead, a visiting engineer of New York, addressed the members on the subject of "Peculiarities and Eccentricities in Conditions of Steel," which was discussed. Adjourned.

OTTO VON GELDERN, *Secretary*.

Civil Engineers' Club of Cleveland.

CLEVELAND, April 12, 1898.*—Prof. C. H. Benjamin then gave a lecture upon the "Evolution of Machine Design," which was illustrated throughout by lantern slides. These views included some very ancient and curious machines, others more modern, but out of date, and some of the latest and most improved patterns. The Professor called attention to faulty designing

*For minutes of proceedings same date see Vol. XX, No. 4, April, 1898, page 53.

in the earlier machines from an esthetic as well as structural point of view, such as the use of carved cast iron legs of Louis XIV style under heavy planers, the imitation of wood framing and paneling in cast iron work and the introduction of other architectural features, all of which were entirely unnecessary to the machines.

At the close of the lecture a discussion of the subject was participated in by Mr. J. R. Oldham, Prof. J. W. Langley, Mr. W. R. Warner and others. On motion by Mr. Ritchie, the thanks of the Club were extended to the Case School of Applied Science for the use of the assembly room and for the interesting exhibition in the laboratories.

After adjournment the members repaired to the Mechanical Building, where Professor Benjamin called attention to various matters of interest, and a light luncheon was served.

Wm. H. Searles, *Secretary.*

Cleveland, May 10, 1898.—The regular meeting was held on May 10 at the office of the Osborn Company, 275 Prospect St. Present, thirty-two members and twenty-two visitors. The meeting was called to order at 8 o'clock by President F. C. Osborn. The minutes of the last meeting were read and approved.

The Executive Board reported the application of Harry Ross Jones for associate membership, and Jacob Dolson Cox, Jr., for active membership.

The Board had made an appropriation of $200 for the Secretary during the present fiscal year, out of which the clerical service of his office was to be paid.

Mr. Reed, for the Library Committee, reported a gift to the Club from Mr. C. O. Palmer of a full set of the Journal of the Association, with permission to make such use of it as the Club may find advantageous. Mr. Reed moved a vote of thanks to Mr. Palmer for the donation, and in case the Journal should be exchanged for other works, the books so received should be inscribed with Mr. Palmer's name, which was unanimously carried.

A proposed amendment to the Constitution was offered and read signed by A. Lincoln Hyde and fifteen other members of the Club. The amendment proposed to substitute for Article I, Section 1, as follows:

Cleveland, May 10, 1898.

To the Civil Engineers' Club of Cleveland:

The undersigned active members hereby propose the following amendment to the Constitution of the Club in accordance with Article IX.

The object of the amendment is to have the name of the Association broad enough to cover its whole membership. It is believed that by assuming a more appropriate and more comprehensive title that a better feeling will be created among the present members, and that more new members will be attracted to the Club.

The Association is made up of mechanical and electrical engineers, architects, chemists, scientists and their associates as well as civil engineers. Acccording to the last Register, fresh from the printer's hands, we find but two out of five honorary members, but six out of fourteen corresponding members, but one out of twenty-two associate members, and but fifty-one

out of one hundred and forty-three active members, or a total of sixty out of one hundred and eighty-four members of all classes that can be classed as civil engineers.

Proposed amendment to the Constitution:

Amendment to Article I, Section 1.

(Strike out Section 1 and substitute):—

SECTION 1. The name of this Association shall be The Cleveland Society of Engineers.

Witness our hands the date above written.

A. Lincoln Hyde,	Robert Hoffmann,
Frank C. Osborn,	August A. Honsberg,
E. E. Boalt,	Walter Miller,
Walter C. Parmley,	John McGeorge,
R. H. St. John,	F. S. Barnum,
John N. Coffin,	H. M. Claflen,
James Ritchie,	Harry S. Nelson,
A. H. Porter,	J. N. Richardson.

Mr. Boalt said, "In order to give fair warning to all members and to give them an opportunity to consider this matter, I move you that the amendment be printed and copies be sent to the members with a letter that the matter will come up for discussion at the next regular meeting." This was seconded and carried. The discussion then proceeded and various possible names were suggested.

Mr. Swasey moved, as an amendment, that the name of this Association shall be The Cleveland Society of Civil Engineers. This was seconded by Prof. Benjamin. Before the vote was taken on Mr. Swasey's amendment, Mr. Cowles, seconded by Mr. Bowler, moved to postpone further discussion to the next meeting. This was carried.

Later in the evening an announcement was made that the next meeting would occur on May 24, and that the discussion of the amendment would then come up. To this Mr. Boalt objected, saying he had mentioned the next regular meeting in his motion. As Mr. Cowles, in his motion, had not done so, on motion, another vote was taken and the sense of the meeting was largely in favor of the postponement of the discussion to the regular meeting in June.

Mr. Bernard L. Green then read a paper entitled, "The Portland Cement Industry of the World." He gave a brief history of the industry and described its present condition in the various countries of Europe and in America, showing a remarkable increase in the production of cement in this country during the last few years.

He described briefly the several methods of manufacture which depend somewhat on the character of the raw material available, and gave the statistics of production in the various countries where Portland cement is manufactured. According to the latest information, the United States ranks fourth among the countries producing Portland cement, the annual output being 2,304,000 barrels, or 6.6 per cent. of the total output of the world.

Germany ranks first with 38.4 per cent, England second with 23.7 per cent. and France third with 8.6 per cent.

The discussion which followed was participated in by Mr. John C. Robinson, of Sandusky; Mr. Chas. B. Stowe and D. S. Clements, of Cleveland, visitors, and by Messrs. Boalt, Baker and other members of the Club.

Before adjournment the President announced that refreshments would be served in the adjoining room, and a vote of thanks to the President for the use of his office, and the entertainment of the Club was unanimously carried.

After adjournment the laboratory of the Osborn Company was visited, the apparatus and specimens of cement examined and the breaking tests of some samples witnessed. W. H. SEARLES, *Secretary*.

MAY 24, 1898.—The meeting was called to order at 8 o'clock by the Secretary. Owing to the absence of the President and Vice-President, Henry C. Thompson was by vote invited to take the chair.

There were present twenty-two members and six visitors. The reading of the minutes was omitted.

The Secretary read a short account of a paper read before the Engineers' Club of Philadelphia, upon a case of jurisprudence in land surveying.

Mr. Joseph W. Willard presented to the Club the first fourteen serial numbers of "Marine Engineering" of New York, including the number for May, 1898, and will furnish later numbers as they are issued. Mr. Richardson, seconded by Mr. Oldham, moved that the books be received, and that the cordial thanks of the Club be extended to Mr. Willard. The vote was unanimously carried.

The paper of the evening was then presented by Mr. Joseph R. Oldham, N.A., on the "International Congress of Naval Architects," held in London last July. He reviewed some of the papers presented at the Congress, and particularly that of Sir E. J. Reed, on the "Advance in the Mathematical Theory of Naval Architecture During the Existence of the Institution."

The question of stability of ships received much attention, and the latest application of water ballast to secure stability. He showed that some vessels having considerable stability in the normal position nevertheless may capsize easily, while others which roll easily nevertheless have a large moment of stability under increasing angles of inclination.

Mr. Oldham described in a very happy way the social features of the Congress and the exceeding hospitality shown to members, with daily excursions to the south of England and an excursion to Scotland.

Passing from the subject of the paper proper, he gave an addendum upon the state of our navy and its possible future developments. Most of our naval vessels have been designed for the protection of our own shores, having therefore rather small coaling capacity which permits of very heavy armament. If we are to take part in the affairs of the world in all quarters of the globe we shall require, like Great Britain, larger ships with high freeboard and larger coaling radius.

The speaker was interrupted by applause at several points, and a very interesting discussion ensued. This was participated in by Messrs. Baker, Thompson, Coffin, J. N. Dodd, Parmley, Richardson and others.

At 10 o'clock the Club adjourned.

WM. H. SEARLES, *Secretary*.

Engineers' Society of Western New York.

BUFFALO, N. Y., MAY 5, 1898.—The April meeting of the Engineers' Society of Western New York was addressed by Major T. W. Symonds, U. S. A., on "Coast Defenses and Fortifications." This subject at a time when preparing for war with Spain was very opportune, and consequently very pleasantly received.

At the May meeting George W. Rafter, expert engineer of Rochester, and member of our Society, read a very interesting paper on the "Run-off of Niagara River." The lecture was replete with interesting data, and was extensively discussed.

H. J. MARCH, *Secretary.*

Association of Engineering Societies.

Vol. XX. JUNE, 1898. No. 6.

PROCEEDINGS.

Engineers' Club of St. Louis.

474th Meeting, June 1, 1898.—The meeting was held at 1600 Lucas Place; with Vice-President Colby in the chair. Thirty-seven members and four visitors were present. The minutes of the 473d regular meeting and the 260th meeting of the Executive Committee were read and approved.

The Secretary announced that he had received applications for membership from Messrs. Albert B. Hazzard and Lovell H. Carr.

Prof. J. B. Johnson then made a verbal report for the committee appointed to memorialize the Secretary of War and the Missouri Congressmen regarding the enlistment of a volunteer brigade of engineers. He stated that telegrams and memorials had been sent as directed and that favorable replies had been received from the Congressmen. It was reported that a regiment of engineers was to be raised in the Mississippi Valley.

Prof. J. H. Kinealy, chairman of the Entertainment Committee, moved that on account of courtesies extended during the excursion of the Engineers' Club to Granite City, on May 28, 1898, the Secretary be instructed to convey the thanks of the Club to the St. Louis Stamping Works, the St. Louis Terminal Railway Association and Mr. Norman W. Eayres. These resolutions were carried by a unanimous vote.

The paper of the evening by Mr. Charles Carroll Brown was then read. It was entitled "The Ethics of Engineering." A definition and a discussion of ethics were first given. The rise of the learned professions from the priests was traced. It was stated that the standard of ethics in business and professional life was lower at the present time than formerly, and the reasons for this were given. The paper closed with a plea for the necessity for a code of ethics in the engineering profession. In the discussion which followed several of the members differed with the author of the paper as to the necessity of a code of ethics and contended that the standard of ethics in the engineering profession had always been a high one.

The discussion was participated in by Messrs. Holman, Moore, Johnson, McMath, Crosby, Eranne, Ferguson, Flad, and Laird.

There being no further business, the meeting adjourned to another room, where lunch was served.

Richard McCulloch, *Secretary.*

Civil Engineers' Club of Cleveland.

CLEVELAND, June 14, 1898.—The regular meeting was held June 14, 1898. In the absence of the President, Past-President Dr. Charles S. Howe was called to the chair at 8.30 P.M. Present, fifteen members and one visitor.

The minutes of two preceding meetings were read and approved.

Messrs. William E. Reed and Arthur A. Skeels were appointed tellers to canvass the letter ballot, which resulted in the election of Harry Ross Jones as associate member, and Jacob Dolson Cox, Jr., as active member.

The Executive Board recommended to letter ballot, for active membership, the names of Robert L. Webb and Francis Henry Treat, both of Cleveland.

A circular letter was read issued by the Austrian Society of Engineers and Architects, announcing the celebration of its fiftieth anniversary to take place next November, and inviting participation.

The chairman of the Programme Committee reported that a paper was expected for this evening, but they were disappointed with regard to it, and that at present no papers are provided for any meeting prior to that of September.

The President announced that the discussion of the Constitutional Amendment, postponed to this time, was in order. Mr. Hyde moved that the discussion be postponed till the regular meeting to be held on the second Tuesday in September. This was seconded by Mr. Reed, and carried.

An informal discussion on the state of the Club was participated in by Messrs. Warner, Hyde, Howe and others.

At 9.15 the meeting adjourned and luncheon was served.

WM. H. SEARLES, *Secretary.*

Technical Society of the Pacific Coast.

REGULAR MEETING, SAN FRANCISCO, JUNE 3, 1898.—Called to order at 8.30 by Vice-President Percy.

The minutes of the last regular meeting were read and approved.

Mr. A. E. Brooks-Ridley read a paper on "Elect ic Elevators," which was discussed by Messrs. Keith, McNicoll, Richards, Frazier and others.

Adjourned.

OTTO VON GELDERN, *Secretary.*

Boston Society of Civil Engineers.

BOSTON, MASS., MAY 18, 1898.—A regular meeting of the Society was held at Chipman Hall, Tremont Temple, Boston, at 8 o'clock, P.M.; Vice-President C. Frank Allen in the chair. Forty-seven members and visitors present.

The record of the last meeting was read and approved.

Messrs. William D. Bullock, William H. McAlpine, Walter E. Spear and William E. Swift were elected members, and Mr. John H. Gerrish an associate of the Society.

Prof. George F. Swain, on behalf of the members of the Society connected with the Massachusetts Institute of Technology, presented a very

life-like crayon portrait, handsomely framed, of Past-President George L. Vose. Vice-President Allen, in accepting the gift, expressed the thanks of the Society and the satisfaction it would give the members to see the portrait hung in our library.

On motion of Mr. Metcalf, the thanks of the Society were voted to the Bath House Committee of the town of Brookline for the courtesies shown this afternoon on the occasion of the visit to the Brookline Bath House.

Mr. Frank O. Whitney then read the paper of the evening, entitled "Co-ordinate Survey of Boston."

The paper was illustrated by a large number of maps and diagrams, showing the work which had been accomplished under the Board of Survey Act of 1891 in relation to plotting a comprehensive street system in Boston.

The paper was discussed by Messrs. A. H. French, E. P. Adams, F. P. Stearns and others.

Adjourned.

S. E. Tinkham, *Secretary.*

Detroit Engineering Society.

Detroit, Mich., June 18, 1898.—The regular monthly meeting of the Detroit Engineering Society was held at the Hotel Ste. Claire, Friday evening, June 17, 1898; President George Y. Wisner presiding; twelve members and three visitors present. Messrs. E. E. Haskell and O. L. E. Webber were elected to resident and non-resident membership respectively. The names of Messrs. L. C. Sabin, J. I. Watson and S. H. Woodard were proposed for membership and referred to the Executive Committee.

The Society then listened to a description of the methods of manufacture of petroleum products by Mr. J. C. Danziger, which was further discussed by Messrs. Dow, Keep, Smith, Mattsson, Raymond, Courtis, Wisner and Williams.

Adjourned.

Gardner S. Williams, *Secretary.*

Meeting of the Executive Committee of the Detroit Engineering Society, held at the Wayne County Savings Bank Building, Friday, June 17, 1898. Present Messrs. Wisner, Smith, Keep, Dow, Field, Pope, Livingstone and Williams.

The applications for membership of Messrs. E. E. Haskell and O. L. E. Webber were approved.

The July meeting of the Society was ordered omitted on account of the annual convention of the American Society of Civil Engineers.

A committee was appointed to arrange for a boat ride upon the occasion of the August meeting.

A committee of three consisting of the President and Messrs. Keep and Goldmark was appointed to negotiate with the Library Commission for the establishment of an engineering reference library, and was authorized to expend fifty dollars in furthering that object and properly cataloguing the books of engineering interest now in the Public Library.

Adjourned.

Gardner S. Williams, *Secretary.*

Montana Society of Engineers.

THE regular monthly meeting of the Society was held in the Society's rooms, in Helena. June 11, 1898. Second Vice-President F. J. Smith called the meeting to order soon after 8 P.M. After the reading of the minutes of the previous meeting, Mr. Walter Harvey Weed, U. S. Geologist, was introduced, and delivered a lecture upon the geology of Butte, Montana. The lecture was illustrated with maps showing the geological formations. After the lecture he answered numerous questions upon the geology of Butte.

The Committee upon Arid Lands reported as follows:

"*Mr. James M. Page, President Montana Society of Engineers,*

"DEAR SIR:—The undersigned, your committee appointed to consider the question of taking action and co-operating with other Western States interested in securing a grant of arid lands, beg to report that they have considered the memorial of the Wyoming State Board of Control, as also a letter of Mr. Elwood Mead, State Engineer, which was submitted to us; and we are of the opinion that it would be desirable for Montana to take such action as Mr. Mead suggests. If our State had a State Engineer, it would be his province to consider such a matter as this, and to co-operate with other States interested in the movement. Since this is not the case, we think it would be advisable for our Society to make an offer of such co-operation and help as may be within its power. We are certainly of the opinion that, in the hands of such a distinguished engineer and able friend of irrigation matters as we know Mr. Mead to be, there can be no doubt but what the action proposed should be productive of some good. The question of detail, as to how this matter is to be carried out, we do not feel able to pass upon at this time, but the idea meets with out approval. If this additional grant of 5,000,000 acres of arid land can be secured for Montana, it will be a new step in the direction of more thorough development of our agricultural resources and protection of the interests of stockmen, and we are inclined to indorse and assist this measure in any way within our power."

FRANK L. SIZER,
PAUL S. A. BICKEL,
A. E. CUMMING.

The Society accepted the report, but took no further action, as it is understood Mr. Mead may visit Montana this year, in which event the question will be considered while he is present.

Frederic Wooster Sherman, manager of the Gold Mountain Mining Company, of Bernice, was elected a member of the Society.

A. S. HOVEY, *Secretary.*

JOURNAL

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CONTENTS AND INDEX.

VOLUME XXI.

July to December, 1898.

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CONTENTS.

VOL. XXI, July-December, 1898.

For alphabetical index, see page v.

No. 1. JULY.

PAGE

The Filtration of Water in Germany. *M. L. Holman* 1
Discussion. *Messrs. Johnson, Holman, Moore, Hermann, McCulloch, Ockerson, Branch, Sanger, Ferguson, McMath, Pitzman, Russell, Colby, Glasgow, Bryan, Trautwine* 7
Notes on the Mathematical Theory of Naval Architecture. *Joseph R. Oldham* 24
Discussion. *Messrs. Thompson, Oldham, Coffin, Parmley, Searles, Hyde* 34
Proceedings.

No. 2. AUGUST.

Abolition of the Grade Crossings on the Main Line of the Boston and Albany Railroad in Newton, Mass.
I. History of the Improvement, and an Account of the Street and Drainage Work Connected Therewith. *Irving T. Farnham* 37
II. The Depression of the Railroad Tracks. *William Parker* .. 50
III. Bridges Over the Railroad Tracks. *W. G. S. Chamberlain* 62
Power Consumption on Electric Railroads. *S. T. Dodd* 67
Discussion. *Messrs. Searles, Sheldon, Dodd* 78
Proceedings.

No. 3. SEPTEMBER.

Deep Bridge Foundations, Atchafalaya River. *C. H. Chamberlin* 81
The Fraser Electric Elevator. *A. E. Brooke Ridley* 92
Discussion. *Messrs. Keith, McNicoll, Richards, Behr, Barth, Fraser, Ridley* 100
Test Meters for Boiler Plants. *Lehman B. Hoit* 112
Discussion. *Messrs. Roberts, Porter, Hoit, Palmer* 116
Proceedings.

No. 4. OCTOBER.

PAGE

Roman Construction. *G. W. Percy*.......... 121
Discussion. *Messrs. Molera, Percy*.......... 133
Improvement of the Mississippi River Delta. *Thomas L. Raymond*... 139
Municipal Control of Public Works. *H. J. Malochee*.......... 149
Sulphuric Acid and the By-Products from Iron Pyrites. *R. G. Ewer*.. 160
Proceedings.

No. 5. NOVEMBER.

The Evolution of Structural Design. *F. T. Llewellyn*.......... 173
The Machinery of Vessels on the Great Lakes and a Synopsis of Rules Compiled by the Great Lakes Register. *John N. Coffin*.... 186
Discussion. *Messrs. Oldham, Miller*.......... 196
The "Econometer." *H. M. Kebby*.......... 198
Discussion. *Messrs. Molera, Kebby, Grunsky*.......... 205
The Electric Motor in Shop and Mine. *Clarence M. Barber*.......... 208
Discussion. *Messrs. Benjamin, Palmer, Sherwood, Gobeille, Bidwell, Houghton, George*.......... 213
State, City and Town Boundaries. *Henry B. Wood*.......... 219
Wooden Stave Pipe *vs.* Riveted Pipe. *D. C. Henny*.......... 239
Discussion. *Messrs. Allardt, Stut, Norboe, Hoskins, Marx, Henny, Wing*.......... 254
Proceedings.

No. 6. DECEMBER.

Addresses delivered at the Meeting to Commemorate the Semi-Centennial of the Boston Society of Civil Engineers, November 11, 1898. Opening address by *Howard A. Carson*, President of the Society 263
Historical address by *Desmond FitzGerald*, Past-President of the Society 268
The Nature and History of Patent Rights. *E. L. Thurston*.......... 281
Discussion. *Messrs. Warner, Thurston, Osborn, Beardsley, Bowler, Palmer, Reed*.......... 292
Levees, with Special Reference to the Red River System. *Frank M. Kerr* 295
The Civil Engineer as a Guardian of the Public Health. *J. B. Johnson* 311
The Civil Engineer and National Public Works. *Geo. Y. Wisner*..... 322
Proceedings.

INDEX.

VOL. XXI, July-December, 1898.

The six numbers were dated as follows:

No. 1, July.	No. 3, September.	No. 5, November.
No. 2, August.	No. 4, October.	No. 6, December.

ABBREVIATIONS.—P = Paper; D = Discussion; I = Illustrated.
Names of authors of papers, etc., are printed in *italics*.

PAGE

Abolition of the Grade Crossings on the Main Line of the Boston and Albany Railroad in Newton, Mass..............P., I., Aug.
I. History of the Improvement, and an Account of the Street and Drainage Work Connected Therewith. *Irving T. Farnham.* P., 37
II. The Depression of the Railroad Tracks. *William Parker.* P., I., 50
III. Bridges Over the Railroad Tracks. *W. G. S. Chamberlain.* P., I., 62
Acid, Sulphuric——and the By-products from Iron Pyrites. *R. G. Ewer*..P., Oct., 160
Addresses Delivered at the Meeting to Commemorate the Semi-Centennial of the Boston Society of Civil Engineers, Nov. 11, 1898.
Opening Address. *Howard A. Carson*....................Dec., 263
Historical Address. *Desmond FitzGerald*..................Dec., 268
Architecture, Naval, Notes on the Mathematical Theory of——. *Joseph R. Oldham*..............................P., D., I., July, 24
Atchafalaya River, Deep Bridge Foundations——. *C. H. Chamberlain*..P., I., Sept., 81

Barber, *Clarence M.* The Electric Motor in Shop and Mine. P., D., Nov., 208
Boiler Plants, Test Meters for——. *Lehman B. Hoit*..P., D., I., Sept., 112
Boston and Albany Railroad, Abolition of the Grade Crossings on the Main Line of the——in Newton, Mass.............P., I., Aug., 37
Boundaries, State, City and Town——. *Henry B. Wood*.....P., Nov., 219
Bridge Foundations, Deep——Atchafalaya River. *C. H. Chamberlain*..P., I., Sept., 81

PAGE

Carson, Howard A. Address delivered before Boston Society of Civil Engineers, November 11, 1898....Dec., 263
Chamberlain, C. H. Deep Bridge Foundations, Atchafalaya River. P., I., Sept., 81
Civil Engineer and National Public Works. *Geo. Y. Wisner.* P., Dec., 322
Civil Engineer as a Guardian of the Public Health. *J. B. Johnson.* P., Dec., 311
Coffin, John N. The Machinery of Vessels on the Great Lakes and a Synopsis of Rules Compiled by the Great Lakes Register. P., D., Nov., 186
Construction, Roman——. *G. W. Percy*....P., D., I., Oct., 121
Crossings, Grade, Abolition of the——on the Main Line of the Boston and Albany Railroad in Newton, Mass....P., I., Aug., 37

Deep Bridge Foundations, Atchafalaya River. *C. H. Chamberlain.* P., I., Sept., 81
Delta, Mississippi River, Improvement of the——. *Thos. L. Raymond.* P., I., Oct., 139
Design, Structural, The Evolution of——. *F. T. Llewellyn*..P., Nov., 173
Dodd, S. T. Power Consumption on Electric Railroads..P., I., Aug., 67

Econometer, The——. *H. M. Kebby*....P., D., I., Nov., 198
Electric Elevator, The Fraser——. *A. E. Brooke Ridley.* P., D., I., Sept., 92
Electric Motor in Shop and Mine, The——. *Clarence M. Barber.* P., D., Nov., 208
Electric Railroads, Power Consumption on——. *S. T. Dodd.* P., I., Aug., 67
Elevator, Electric, The Fraser——. *A. E. Brooke Ridley.* P., D., I., Sept., 92
Evolution of Structural Design. *F. T. Llewellyn*....P., I., Nov., 173
Ewer, R. G. Sulphuric Acid and the By-Products from Iron Pyrites. P., I., Oct., 160

Filtration of Water in Germany. *M. L. Holman*....P., D., I., July, 1
FitzGerald, Desmond. Historical Address Delivered before Boston Society of Civil Engineers, November 11, 1898....Dec., 268
Foundations, Bridge, Deep——Atchafalaya River. *C. H. Chamberlain*....P., I., Sept., 81
Fraser Electric Elevator, The——. *A. E. Brooke Ridley.* P., D., I., Sept., 92

Grade Crossings, Abolition of the——on the Main Line of the Boston and Albany Railroad in Newton, Mass....P., I., Aug., 37
Great Lakes Register, Machinery of Vessels on the Great Lakes and a Synopsis of Rules Compiled by the——. *John N. Coffin.* P., D., Nov., 186

Health, The Civil Engineer as a Guardian of the Public——. *J. B. Johnson*....P., Dec., 311
Henny, D. C. Wooden Stave Pipe *vs.* Riveted Pipe...P., D., I., Nov., 239
Hoit, Lehman B. Test Meters for Boiler Plants....P., D., I., Sept., 112
Holman, M. L. The Filtration of Water in Germany...P., D., I., July, 1

PAGE

Improvement of the Mississippi River Delta. *Thos. L. Raymond.* P., I., Oct., 139
Iron Pyrites, Sulphuric Acid and the By-Products from——. *R. G. Ewer*....P., I., Oct., 160

Kebby, *H. M.* The Econometer....P., D., I., Nov., 198
Kerr, Frank M. Levees....P., Dec., 295

Levees. *Frank M. Kerr*....P., Dec., 295
Llewellyn, F. T. The Evolution of Structural Design....P., Nov., 173

Machinery of Vessels on the Great Lakes and a Synopsis of Rules Compiled by the Great Lakes Register. *John N. Coffin.* P., D., Nov., 186
Malochee, H. J. Municipal Control of Public Works....P., Oct., 149
Mathematical Theory of Naval Architecture, Notes on the——. *Joseph R. Oldham*....P., D., I., July, 24
Meters, Test——for Boiler Plants. *Lehman B. Hoit*...P., D., I., Sept., 112
Mississippi River Delta, Improvement of the——. *Thos. L. Raymond.* P., I., Oct., 139
Motor, The Electric——in Shop and Mine. *Clarence M. Barber.* P., D., Nov., 208
Municipal Control of Public Works. *H. J. Malochee*....P., Oct., 149

National Public Works, The Civil Engineer and——. *Geo. Y. Wisner.* P., Dec., 322
Nature and History of Patent Rights. *E. L. Thurston*...P., D., Dec., 281
Naval Architecture, Mathematical Theory of——. *Joseph R. Oldham.* P., D., I., July, 24
Notes on the Mathematical Theory of Naval Architecture. *Joseph R. Oldham*....P., D., I., July, 24

Patent Rights, Nature and History of——. *E. L. Thurston.* P., D., Dec., 281
Percy, G. W. Roman Construction....P., D., I., Oct., 121
Pipe, Wooden Stave——*vs.* Riveted Pipe. *D. C. Henny.* P., D., I., Nov., 239
Power Consumption on Electric Railroads. *S. T. Dodd*..P., I., Aug., 67
Public Works, The Civil Engineer and National——. *Geo. Y. Wisner.* P., Dec., 322
Public Works, Municipal Control of——. *H. J. Malochee*....P., Oct., 149

Railroads, Electric, Power Consumption on——. *S. T. Dodd.* P., I., Aug., 67
Raymond, Thos. L. Improvement of the Mississippi River Delta. P., I., Oct., 139
Register, Great Lakes, Machinery of Vessels on the Great Lakes and a Synopsis of Rules Compiled by the——. *John N. Coffin.* P., D., Nov., 186
Ridley, A. E. Brooke. The Fraser Electric Elevator...P., D., I., Sept., 92
Riveted Pipe, Wooden Stave Pipe *vs.*——. *D. C. Henny.* P., D., I., Nov., 239
Roman Construction. *G. W. Percy*....P., D., I., Oct., 121

PAGE

State, City and Town Boundaries. *Henry B. Wood*..........P., Nov., 219
Stave Pipe, Wooden——*vs.* Riveted Pipe. *D. C. Henny.*
P., D., I., Nov., 239
Structural Design, The Evolution of——. *F. T. Llewellyn*...P., Nov., 173
Sulphuric Acid and the By-Products from Iron Pyrites. *R. G. Ewer.*
P., Oct., 160

Test Meters for Boiler Plants. *Lehman B. Hoit*......P., D., I., Sept., 112
Thurston, E. L. Nature and History of Patent Rights...P., D., Dec., 281

Vessels, Machinery of——on the Great Lakes and a Synopsis of Rules Compiled by the Great Lakes Register. *John N. Coffin.*
P., D., Nov., 186

Water, Filtration of——in Germany. *M. L. Holman*..P., D., I., July, 1
Wisner, Geo. Y. The Civil Engineer and National Public Works.
P., Dec., 322
Wood, Henry B. State, City and Town Boundaries..........P., Nov., 219
Wooden Stave Pipe *vs.* Riveted Pipe. *D. C. Henny*...P., D., I., Nov., 239

ASSOCIATION OF ENGINEERING SOCIETIES.

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VOL. XXI. JULY, 1898. NO. 1.

THE FILTRATION OF WATER IN GERMANY.

BY M. L. HOLMAN, MEMBER OF ENGINEERS' CLUB OF ST. LOUIS.

[Read before the Club, May 18, 1898.*]

IN the following paper I shall describe German practice in filtration as it appears from an engineering standpoint, divested of all scientific superfluities, and shall give only those features which pertain directly to construction and operation.

The work in Germany which may be taken as typical of plain or natural sand filtration is that at Hamburg. The National Board of Health of the German Empire requires that filtered water shall contain less than 100 bacteria per cubic centimeter. This is an arbitrary standard first selected as the result of laboratory experiments, and then adopted as the official standard, after considerable practical experience in the larger cities and works of Germany.

The Hamburg filter basins are eighteen in number, and are each about 70 meters wide and about 100 meters long. They are rectangular in plan, with rounded corners. The sides of the basins slope at an angle of about 45°, and the floor and slope are formed in the manner usual in reservoir construction. The floors and the inner slopes are covered with puddle, which is protected by concrete and brick. The brick construction covers the floor and about half of the slope. The upper half of the slope is covered by a very smooth concrete, similar to what we have here in our granitoid pavements. At appropriate places in the bottom of the reser-

*Manuscript received June 9, 1898.—Secretary, Ass'n of Eng. Socs.

voir channels are formed in the brick for the purpose of leading off the filtered water. For a portion of their depth these channels are countersunk in the bottom of the basin, and are afterwards completed by laying brick loosely along the sides and tiling over the top. After these channels are completed the filter is built up to the top of the channels, beginning with broken stone, following with gravel, then with fine gravel, then with coarse sand, and over all is placed the working layer of sand, one meter thick and of a fineness depending somewhat upon the character of the water, although the question of fineness has not been given much study in Germany. You will see that a meter in depth of sand is the working body of the filter, the materials under that simply supporting the sand. The entire depth, sand and all, acts solely as a support for the blanket or film of bacterial jelly or slime, which naturally forms while the raw or foul water rests upon the filter. Of course, in building up the filter bed great care must be taken to fill the smallest crevices, so that the entire body is sound and uniform, and so that an even surface of sand is left on the top of the filter. The filter is then set to work at its normal rate. This rate varies in different cities, the maximum rate in any city being 125 millimeters per hour, while at Hamburg the maximum rate is 100 millimeters per hour; that is, the velocity with which the water passes through the sand.

Now it is found that after the filter bed has been at work, for a time varying from three days to a week or more, depending upon circumstances that are not thoroughly understood, there appears upon the surface of this sand, and in the upper portion of it, a veil or film of slime. As soon as the filter is put at work the output is examined. This examination goes on for a time, and when it is found that the output contains less than 100 bacteria per cubic centimeter the filtered water is used. Until then it is wasted. The work of the filter then goes on, examinations being made daily and recorded; and as soon as the output shows an increase up to about 75 bacteria per cubic centimeter the filter is put out of work and cleaned. At times the filter has to be cleaned because the output becomes too small, although the head on the filter has not reached the maximum, and athough the output of filtered water is still within the required limit of purity. The maximum head allowed for forcing the water through the filter is 0.6 meter. The total depth of water above the sand is 1.1 meters. Each separate filter is examined and kept track of very carefully. At times the filter will suddenly begin to discharge water containing a surplus of bacteria. Those engaged in the practical operation of the

works in Germany and in the practical study of them, and upon whom devolves the care of furnishing the city with filtered water, are as yet unable to account for this action. They attribute the entire operation of the filter and of the bacterial purification to the change taking place in the water passing through the slime or blanket which forms on the surface. The change, as near as I could ascertain from them, is a natural process, the slime being a place where the bacteria stop by preference, and where some of them die, some of them are eaten up, some stay because they like it better than anywhere else; the idea being that the operation is confined exclusively to the slime, and is not in anywise chemical in its action. The engineers in charge of the filters of Hamburg, Bremen and Worms knew nothing of the "nitrifying action" talked of and written of in this country, their idea being that the action of the filter excludes the bacteria only.

When the filter needs cleaning the water is drained off and an examination is made of the upper surface of the sand. It is then found that the slime formation has penetrated to different depths in the sand, varying with the time of the year and other conditions. The cleaning is carried down to twice the depth to which the sand shows contamination, varying from a half an inch to a good stiff spading, according to the time of the year and the conditions under which the filter is worked. The labor of cleaning the filter is exceedingly heavy. It is accomplished by means of small railroad cars on a narrow-gauge track. After the filter has been cleaned it is again set to work, and this process is repeated until only about 16 inches of sand are left, when the filter is again restored to its original condition.

Now the cleaning of a filter in winter (and I speak only of open filter basins such as they have at Hamburg) is a complicated process, both expensive and inefficient, and is accomplished by the use of a machine which I will try to describe.

A cut is made through the ice on the side of the filter, and the machine shown in Figs. 1 and 2 is inserted under the ice. This machine is dragged along, the float being held against the ice by its buoyancy, and the bag dragging on the sand. That operation scrapes off a small amount of the sand and slime, which accumulates in the bag. When the bag reaches the other side of the filter it is drawn up to the bank, and reversed by means of a rope. The process goes on, the machine traveling back and forth across the filter, until all the matter to be removed has been scraped into piles at the sides of the filter. About two scrapings under the ice are about all that can be given to a filter. This scraping reduces the

output of the filter about one-half. The dragging action of the canvas bag seems to plaster the surface of the sand and tighten it up so that afterwards the water finds increased resistance to its passage through the bed.

The sand that is removed is cleaned by a machine, Figs. 3 and 4, which requires 20 cubic meters of filtered water to clean one cubic meter of sand. The sand is fed into a trough with a stream of water. From the bottom of this trough arises a pipe which is fed by an ejector nozzle running filtered water under a very high pressure; this nozzle throws the sand to the top, where it is sent back or travels over into a trough and runs down into a second truncated pyramid with a similar ejector. This process is continued until the sand has had a thorough washing, and is then so clean that a handful of it thrown into filtered water will not produce the slightest cloudiness in the water.

The building and loading, or preparing, of the filters is very expensive, and the operation and cleaning of the beds are also exceedingly expensive, notwithstanding the cheapness of labor in Germany. With us these operations would of course be still more expensive.

The Bremen filters are very similar to those at Hamburg, with the exception that they are built in covered vaults. The only difference in the operation is a modification in the cleaning as practiced in winter. Of course, with the filter in a covered vault the workmen can get at the top of the sand and can lay their small tracks running narrow-gauge cars, soon getting the sand out for the washing machines.

The sand-cleaning machine used at Berlin is somewhat different from those in Hamburg. At Berlin the sand is run through a long cylinder. It is fed to the top of the cylinder with a spout and comes out of the lower end of the cylinder, filtered water having been fed through at the same time. The sand runs off in a series of troughs, and is shoveled out of the last trough by hand.

The most difficult water in the German Empire to filter or handle is that of Bremen. The river is very small and very foul, and it has been found necessary to adopt a system of double filtration. The filters are similar to those at Hamburg, with the sole exception of the sides, which are vertical at Bremen instead of sloping, as at Hamburg. The study of the film which forms on the sand has been carried further at Bremen than at any other filter plant. It was found that with one filtering of the water it was impracticable to obtain the standard required by the National Health authorities, and it was then decided to try whether further purifica-

tion could be obtained by again passing the filtered water through a second film, the two filter beds working "in series," to use a term borrowed from the electric fraternity. The raw water is introduced on filter No. 1, passes through and is syphoned over, as raw water, to filter No. 2. It is found that passing the water from the first filter through the film on filter No. 2 improves the character of the water to an extent that warrants its use. A matter of peculiar interest, resulting from the examination of the Bremen filters, is that the slime, film or "blanket," which does the work, cannot be formed from the partially filtered water which had gone through filter No. 1; so that, in order to prepare the filters for work after filter No. 2 has been cleaned, it must be used a short time as a primary filter, in order to accumulate the necessary slime on top of the sand. It is then put in as the secondary filter, and runs for a considerable time. This fact, as practically demonstrated at Bremen, was conclusive evidence to me that the entire process of filtration, as practiced in Germany, depends simply upon the securing of the film on the top of the sand, and its scientific and skillful handling. This position is that of the engineers in charge of the works at Berlin, at Bremen and at Hamburg.

I also examined carefully the Fischer sand-plate filter in Worms. The city of Worms having reached the capacity of its filter plant, which was a natural sand filter similar to the later one built in Berlin, it became necessary to increase that capacity. The engineers in charge of the filtering works, and the scientific men having that matter in charge, being of the opinion that the filtration process, so far as bacteria was concerned, was due entirely to the film, set to work to devise a means of supporting this film more cheaply than by a horizontal layer of sand. Their studies resulted in the production of an artificial hollow stone block, called an "element." This element, as usually built, is a rectangular vertical box one meter square. The necessary thickness of sand was found, by preliminary experiment, to be 2½ to 3 inches. At Worms these elements were placed in one of the vaults where the plain sand filter had been used. The first experiment proving successful, the number of units was afterward increased, increasing eight-fold their capacity for aggregate output of filtered water per acre; that is, with the same area eight times the former amount of filtered water could be furnished. The new Wormser filter is worked exactly the same as a sand filter, the raw water percolating through the elements, and the filtered water runs off through the clear water pipe. When the filter is first put to work the water is allowed to run to waste, as in the plain sand filter, until the output

shows the requisite purity of less than 100 bacteria per cubic centimeter. As soon as this standard is reached the filter is put to regular work, the blanket having formed over the working surface of the elements. The output of the filter is examined, the same as with the plain sand filter. The head is the same and the average velocity through the stone the same. When the output falls below the requirements, or when the number of bacteria begins to exceed the limit, the filter is cleaned, not, as in the sand filter, by removing the sand, but by reversing the current of filtered water back through the element; that is, the slime formation is driven back and the porosity of the stone is restored by a counterflow of filtered water. When this is skillfully done the film is not totally destroyed, and the filter, after cleaning, is ready to proceed at once with the work of furnishing filtered water of the required standard. This system has been in use successfully in Worms for some years.

The waters treated in the plants which I have described do not carry a very large amount of sediment. The sediment-carrying waters on the continent are mostly in Russia and a part of Austria. Attempts have been made to filter those waters, especially at Warsaw, in Poland, on the English or plain sand system. But while the bacterial film or blanket is formed, and while the output, from a bacteriological standpoint, is good, the sand filter has not succeeded in stopping the finely divided inorganic sediment. At several places in Germany a chemical treatment is used for freeing the water from inorganic sediment and from iron. For some reason, which I could not ascertain, the National Health authorities of Germany forbid the use of aluminum sulphate in filtration. I understand, however, that their objection is that the treatment renders the water acid. The authorities do, however, allow treatment of water by means of an iron solution. This iron solution, used preliminary to filtering it, forms a coagulant, which, as with sulphate of aluminum, is strained out of the water afterwards by filtration. Where a coagulant is used, subsequent filtration is simply a straining. The film or blanket, which forms in the plain sand filter, is not formed, and is not sought for. In filtration after coagulation the object is simply to use a sieve fine enough to keep out the coagulated matter and the iron which has been introduced into the water, or which may have been in the water before it was treated.

All of the engineers with whom I talked on this matter, and they all spoke English with the same difficulty that I spoke German, agreed that in the treatment of water containing the amount

of sediment which the waters of some rivers of Russia or those of the Mississippi River contain, a preliminary treatment would be necessary, and that it was exceedingly doubtful whether the film on the surface of the sand would do the bacteriological work, the reason being that the preliminary sedimentation would deprive the water of its stock of bacteria, depleting it to such an extent that the bacteria left would not suffice to form the film. This was indicated by the result at Bremen, where, although the partially filtered water contains more bacteria than allowed by the health authorities, the film necessary for successful filtration is not formed.

The amount of sediment in our water here, when I explained it to them, was of course beyond their comprehension. While they were too polite to contradict me, I perceived that they doubted my assertions. They were strongly of the opinion that preliminary sedimentation and coagulation would be necessary. One thing, among others, I learned, and that is that there is no hole so small that the bacilli can not get through it.

DISCUSSION.

PROF. JOHNSON.—Is the iron process mentioned the Anderson?

MR. HOLMAN.—No. It consists in the introduction of iron chloride into the water. The problem is to bring the cost of the manufacture of the chloride within the financial reach of the works.

PROF. JOHNSON.—Is the action of the chloride similar to that of aluminum?

MR. HOLMAN.—No. The iron chloride forms iron hydrate in the water, while aluminum forms aluminum hydrate.

PROF. JOHNSON.—Does not coagulation take place in the Anderson process?

MR. HOLMAN.—Yes.

MR. MOORE.—Are mechanical filters used in Germany?

MR. HOLMAN.—No. Their use is forbidden, as is also that of the individual house filter. Up to within a very short time the Germans have failed to discover a house filter giving sufficient protection against bacteria. Even the Pasteur failed to meet their requirements. The filtration plants are built and operated by the municipal authorities, under the supervision of the National Health authorities of the empire. Experiments have, however, been made with appliances imported from the United States, in connection with the Worms element, which has passed the necessary inspection and fulfilled all the requirements of the health authorities.

As a house filter the Worms element, when properly handled, is as much proof against bacteria as the municipal filter.

Mr. Hermann.—Can you explain briefly the operation of the mechanical filter?

Mr. Holman.—The mechanical filter, as generally used in this country, consists of a shell or tank, in which a considerable depth of sand is placed. At the bottom is a fine strainer, with tubes for drawing off the filtered water. On top of the sand is introduced the raw water and a proportionate amount of aluminum sulphate or alum, varying from one grain to the gallon up or down, as the case requires. This coagulant forms in the water a precipitate, which is caught on the surface of the sand. When the sand becomes so clogged with the precipitate that the output is materially diminished, the filter is washed by reversing the direction of the current of water through it. In this country raw water is sometimes used for washing. This throws the raw water on the clean side of the filter, and of course leaves the sand, after washing, with whatever bacteria may have been carried to it by the raw water. The filter is then put to work and allowed to run until the water runs clear, without reference to its bacteriological condition. In the tanks are placed revolving rakes, worked by machinery, in the sand during washing. The mechanical filter, as used here, acts simply as a strainer. The bacteriological results have not been carefully investigated as yet. The mere fact that various filter companies, in reporting the operations of their filters, state the percentage of bacteria removed, does not prove sufficient knowledge of the subject. The percentage of bacteria removed is not the question, but the question is the *number* that are left in the water.

Mr. McCulloch.—What is the number of bacteria in Mississippi River water?

Mr. Holman.—The number varies widely with the season of the year.

Mr. McCulloch.—Is it less when the water is very muddy?

Mr. Holman.—No. It is less in winter, when the water is cool. We find practically that most of the bacteria go with the mud. After the water is allowed to settle for a considerable time it is found quite free from bacteria, but the mud is very prolific.

Mr. Ockerson.—Does this film form on vertical surfaces as readily as on horizontal surfaces?

Mr. Holman.—The results indicate that the film forms not only on the outer surfaces, but also in the interstices between the grains of sand. The health authorities of Germany make no dis-

tinction as to the character of bacteria in filtered water. They simply make the broad requirement that there shall be no more than 100 bacteria per cubic centimeter, regardless of the kind.

Mr. Ockerson.—Have the Worms elements been tried on muddy water?

Mr. Holman.—They have no muddy water to try it on. The Rhine at that place gets slightly muddy, so that they would clean their old sand filters as often as once in three days. But what they call muddy water we would here call fairly clear water.

A Member.—What is the advantage of compressed air? I have seen it used in one filter, divided very finely and forced in.

Mr. Holman.—You may refer to the mechanical device that produces a back flow through the filter. That you will find in the filter of the American Tripoli Company, which consists of a tripoli stone cylinder inside of a small iron boiler. The raw water is allowed to enter from the inside of the stone and filter outward though it. The upper part of the iron boiler is used as an air chamber. The filter is cleaned by reversing the current of the water, the flow being due to the elasticity of the air in the upper part of the chamber; but the compressed air is not run through the stone.

A Member.—In the filter to which I refer compressed air is brought through a pipe and forced through the sand.

Mr. Holman.—I have not seen it. I should anticipate that it would be very detrimental, so far as the bacteriological result is concerned. In Germany the effort is to keep the sand free from air, so as to keep the sand compact, in order that it may afford a firm support for the film.

Mr. Branch.—What was the principle of that mechanical filter used at Worms; was it a stone filter?

Mr. Holman.—The term "mechanical filter" is used to designate a sand filter in which the bed is cleaned by revolving rakes driven by machinery while the current is reversed. The Fischer sand-plate filter, to which I have referred as the Worms element, is simply a hollow square slab of artificial stone, which is set up on its edge, through which the water filters inwardly, and which is cleaned by merely reversing the current. The problem was to economize space by making sand stand up on edge, and it was solved by mixing with the sand a sufficient amount of glass and subjecting the mixture to a temperature that renders the glass plastic and sticky. The result is a porous stone, composed of sand and glass, and not affected by any ordinary waters or ordinary acids.

Mr. Branch.—Is there any danger of one of those elements getting broken?

Mr. Holman.—That may happen. And in arranging their filter plants the elements are arranged in batteries, so that the output of the individual batteries can be examined independently of that of the whole plant. Thus, the output from each filter at Worms is carefully examined every day, so that any difficulty can be detected.

Mr. Sanger.—Then a fault might run twenty-four hours without being found?

Mr. Holman.—It might run twenty-four hours. They generally take two samples a day from the filter.

Mr. Ferguson.—Is the nature of the bacterial film sufficiently well understood to afford an explanation why, at the city of Worms, when the current is skillfully reversed, the film remains intact and serves the purpose of a new film?

Mr. Holman.—A large portion remains on. Of course some is torn off. Just what that film is I could not find out, and the engineers handling the problem do not seem to care to know. They get certain results, meeting certain requirements of the German Government; and with what particular bacteria constituted the film they had no concern.

Prof. Johnson.—Do you know whether reversing the flow in the Pasteur filter, in muddy water, cleans it completely or only partially?

Mr. Holman.—If the reversed current is under sufficient pressure it will clean the tripoli stone filter of tubular form, provided the reversal is made from the outside to the inside, but not otherwise. The filter being circular in shape, the current passing inward acquires increasing velocity.

Prof. Johnson.—Pasteur tubes could not be cleaned in that way?

Mr. Holman.—I should say not. It is possible with the tripoli stone, but I have not tried it with others.

A Member.—How much water per inhabitant do the Germans use, as compared with what we use here?

Mr. Holman.—A little less than half.

A Member.—How many gallons do we use now per head per day?

Mr. Holman.—From about seventy-five to a little over one hundred, depending upon the time of the year.

A Member.—Is the meter system used in Berlin?

Mr. Holman.—Yes, the meter system is used in all the German municipalities.

A Member.—As well as in England?

Mr. Holman.—Yes.

A Member.—Is the entire supply in every case filtered, or is a distinction made as to the purpose for which the water is to be used?

Mr. Holman.—In cities having a filter supply the entire supply is filtered. In some cities the double system of supply is used, as at Cologne, where they have one supply for domestic use and another for general use. But that is quite rare. Hamburg filters its entire supply, and so do Berlin, Bremen and Worms.

Mr. Robert Moore.—Several years ago I gave to this subject sufficient study to impress me with the great value of the recent discoveries in filtration, and of their great and growing importance to our own city.

Nearly every city suffers sooner or later from the injurious effects of the increasing density of population in the watershed from which it takes its water supply, so that a city which to-day has a pure and wholesome supply is apt in a few years to find it polluted and dangerous. As showing how danger of this sort may be averted, the discovery, made ten or fifteen years ago, that filtration through sand is not only a process of clarification, but also a process of biological purification, is to all cities one of the most important discoveries ever made. No city can safely neglect the study of this subject in the light of its own local conditions, so that when the need arises it may be ready at once to adopt those methods which are best suited to its own peculiar needs. And in view of the approaching completion of the Chicago drainage works, which will throw into the Illinois River, and thus into the Mississippi, an enormous volume of sewage, there can be no doubt that an exhaustive study of the best methods of filtering our own water supply is a matter of the utmost importance to the city of St. Louis. I am glad, therefore, that Mr. Holman is at work upon this subject, and I trust he will receive from the members of this Club all the encouragement and assistance in their power.

With such a study, many of the difficulties with which filtration is now beset will undoubtedly disappear. For example, the cost of cleaning filters, to which Mr. Holman alludes, will, I am sure, be very greatly reduced. In Europe the problem of the reduction of the labor cost of any process receives far less study than in America. Methods are contentedly borne there which would not be tolerated in this country. For example, at the sewage

reservoirs in Boston harbor the work of operating the gates which discharge the sewage is done by three or four men, whilst at Barking, near London, the same work requires a small colony. The reason for the difference lies in the fact that at Boston the gates are operated by machinery, which requires only to be started. I feel confident, therefore, that, when we get seriously to work at the problem, the labor cost of operating and cleaning filters will be so greatly simplified and reduced as to be no longer burdensome.

Prof. Johnson.—Mr. Chairman, I think the best service the rest of us can render to this city and the Club is not to explain how our water shall be clarified, or to theorize on how it ought to be done, but to insist that it shall be done. I know of nothing that could possibly happen to St. Louis that would be of such tremendous value commercially, to say nothing of its sanitary value, than the filtration, or at least the clarification, of our entire water supply.

We who have lived here for some time forget how we regarded the character of the water supply when we first came, and we now rather ignore it and laugh at the fuss that our friends make over it when they come here and see it for the first time. But really we are regarded by other communities as little better than the inhabitants of the Philippine Islands, or of some other half-civilized region. And we cannot convince them that this water is fit to drink or to use in any domestic way.

I came to St. Louis from Detroit, had gone to school in Michigan and had been for many years in what you might call, with reference to St. Louis, the "Chicago atmosphere." I now think St. Louis is one of the best cities in the world. We who know about these matters know that, on the whole, our water supply is very wholesome. The mere fact that we have the lowest city death rate in the world is sufficient to show that our water supply is not unwholesome. Mr. Holman said the sedimentation it gets in the settling basins removes the bacteria so thoroughly from the water that it is no longer able to furnish the seductive coating required to remove the few that are remaining. I sometimes say to my friends of Eastern origin and prejudices that the water here, after the mud is removed, is very much better for having had the mud in it. This proposition is a novel one to them, but it is not so to us; we know that the Missouri River water, after being clarified, is very much better than the upper Mississippi River water, from the very fact that the Missouri water has had the mud in it. What difference does it make whether we filter the water through the ground or filter the ground through the water? There is no difference. Now we filter our ground through the water; we make

it almost thick with good clean clay and then we let it settle, and that filters the water just as effectually as though we filtered our water through the ground.

The health argument is not the strongest one in favor of filtering our water, and I dislike to see it pressed, because, in the first place, I believe there is not much force in it, and, in the second place, it unnecessarily alarms both our own people and strangers to our great disadvantage and to no profit. But we can work the commercial argument, the idea that money spent in clarifying our water supply is going to bring many times its value in a financial return. This is an argument that appeals to every citizen, and especially to the people who pay the taxes and water rates. I think merely clear water would be worth millions of dollars a year to this city at a small calculation, and the benefits would appear in a thousand ways, to say nothing of water entirely free from bacteria. Perhaps when filtered it would not be very much freer from bacteria than if simply clarified; but in either case it would be a water which would be decent, and would be like the water that other people use, and we would be regarded as at least civilized and white—which is more than can be said now.

Mr. Robert E. McMath.—Our Water Commissioner had the enterprise and the good luck to go to the other side of the water and learn something, without any cost to the city of St. Louis, and he comes back and generously gives the city the benefit of what he learned. I am rather under the impression that this comes about fifty years ahead of time; that is, what he has learned is so far in advance of the ideas prevalent in this community that he will be a very old man before the community catches up with him.

As Prof. Johnson puts the situation, one important thing which we can expect to gain by the betterment of our water supply is to render it less repulsive to the stranger. I well remember the first time I ever turned water into a washbasin in the city of St. Louis, and the astonishment with which I waited to see if it would not get a little better. I remember the repugnance with which I undertook to wash my face in such stuff, but that, you must remember, was a good way back. You young men never saw such water coming from a hydrant.

For a good many years the city of St. Louis has been trying to rid herself of that trouble. When it inaugurated the system of settling basins it was expected that the quality of our water supply would be rendered entirely satisfactory. For a time it was satisfactory, because of the contrast with what we had had before. But time passed on and the basins had to be worked far beyond their

capacity. Next works were completed at the Chain of Rocks. I think there was some further disappointment then, for the benefit that was realized fell, like other things, below the expectations. The next step in the process, according to Mr. Holman's logic, is that the water has got to be clarified, both on account of Prof. Johnson's argument and as a preliminary step to the further and complete purification which it is proposed to accomplish by filtering.

Now I am of the opinion that, for a good while to come, our people will be satisfied if they get the full result of clarification, so that the water which comes to them from the hydrant will be entirely free from mud and from its present repulsive appearance. I am inclined to think it will be a long time before we deem it necessary to go to the additional expense of filtering all the water used in the city of St. Louis, as that would render it absolutely necessary that the supply should be delivered through a meter, and every man would pay for the number of gallons that he uses or wastes.

Mr. Holman has not succeeded in making me an advocate of the filtering of the whole water supply, simply for the reason that, since I have been connected with the city affairs, I have got into the habit of being satisfied to do the best we can, and to let the ideal condition wait for future generations to develop. I think the present generation of the city will be very well content if they realize a complete clarification.

The situation, as I view it, is: Mississippi water during three-fourths of the year is so heavily charged with mud that it would clog any kind of filter. As the first preliminary to filtering, it must therefore be cleared of nearly all of its mud burden. It is not practicable to furnish sufficient area of settling basins to clear our entire water supply by natural sedimentation. Hence resort must be had to some form of coagulant. Clarification by a coagulant will be so complete as to remove the repulsive appearance, and the water, after the sedimentation secured by the use of a coagulant, will have so small a residue of bacteria that the essential bacterial film will be very slow of formation, if formed at all, be the surface sand or stone, natural or artificial. The logic is clear to me up to the point of clarification, but it fails as yet to lead me to advocate filtration for the entire water supply of St. Louis.

Mr. Julius Pitzman.—To the matter of sanitary filtration of the water used in St. Louis I have never given much attention, but I agree with Prof. Johnson that it is of the utmost importance, for the development of our city, to take initiatory steps for the

clarification of the water; and we should, furthermore, pay some attention to the condition of the river and, as far as practicable, prevent its pollution.

In a very short time the sewage of Chicago will be discharged through a canal into the Illinois River, which empties its waters into the Mississippi River some twenty miles above St. Louis; and, irrespective of the question whether or not the flow of the sewage thus discharged will have an injurious effect upon the health of our inhabitants, a large portion of our population will think that it has, and will ask for the abatement of this nuisance. We may therefore have to file an injunction against Chicago, to prevent the further discharge of sewage. In case such suit is brought we will find ourselves in the position of asking the abatement of a nuisance, while we ourselves are discharging all sewage and offal into the river and creating a similar nuisance.

If a person of æsthetic refinement visits the river bank or takes a sail in front of our city he will return in disgust, and with a very poor opinion of the people who permit the river to be so horribly polluted. It seems to me that the time will soon come when cities will be prevented by proper authorities from discharging their sewage and offal into rivers, and when they will be obliged to build intercepting sewers, so as to separate sewage from storm water.

As the filtration or clarification of all the water used by us will greatly increase the expense connected with our water works, it has been suggested to introduce water meters to prevent the wasting of water. Dr. Glasgow has remarked that he considered it inadvisable to stop the waste, and I have heard the argument frequently made by prominent physicians that the waste water flushed the sewers. I wish to call their attention to the fact that all the water used by our city is pumped through four or five pipes of 36 inches diameter, and that if this quantity of water is discharged through the district sewers, with hundreds of branches, each having a diameter of at least 12 inches, it cannot possibly flush all of such sewers or effect any improvement of their sanitary condition.

Arrangements could easily be made by which, during a dry season, the valves of the water pipes are opened and the water thrown into the manholes at the summits, and thus one set of district sewers after another could be flushed in a systematic and effectual manner at a very much smaller expense than by wasting over ten million gallons of water daily without the slightest benefit to the sanitary condition of our sewers.

Mr. Russell.—Some years ago, when Colonel Flad was President of the Board of Improvements, the St. Louis Water Department made some experiments on filtration. At that time Colonel Flad had an idea that upward filtration was the proper thing, and so a filter was fitted up (10 feet square I think it was) to try upward filtration. We also had some small experimental filters made upon the European plan. Those filters were operated for quite a long time, and we have the records of all those experiments. To the best of my recollection, the experiments showed pretty conclusively that sand filtration, as nearly as could be told from such a small experiment, is a very expensive process with our water. The sand would have to be scraped very frequently, and the capacity of an acre of sand filter would be very small at a time when our water was bad.

Since Mr. Holman has been Water Commissioner we have had a few small experimental filters built. They were all of the so-called "mechanical" type. The largest was about four feet square. They were used experimentally for some months, and a great many difficulties were met with. The quality of the water changed constantly, and there were many things that affected the filtration, *e.g.*, the temperature affects the rate of filtration. In fact, there are many difficulties in getting the mechanical filter to work properly, and experimenting with it is very unsatisfactory, unless there is a large fund at disposal.

In our mechanical filters aluminum sulphate was used through all the experiments, and pretty fair results were obtained on the whole; but it is difficult to tell, from a small experiment, just what would be the cost of a plant of sufficient capacity for our whole water supply. We have not had experiments enough to determine that. We have made several plans and estimates of the cost of a plant to filter our supply, both on the American and also on the European system. Filtration and the use of meters must come together. If we have filtered water we must reduce the consumption by the use of meters. Now these meters cost a good deal of money, but they would check the increasing consumption of water. It has been the history of all large cities that the rate of consumption per capita increases steadily and at a quite rapid rate. This is true of all the large cities of America, and I believe is also true of some cities in Europe.

Now the use of meters would hold this growth in check to a large extent, reducing the rapid increase in the per capita consumption. I have attempted, with insufficient data, to estimate the reduction and the cost of filtration, and I believe that the city,

over a number of years, would actually be spending less money by having filtered water and using meters than it would spend under the present system, allowing the consumption of water to increase as it does now.

I think Prof. Johnson hit very close to the mark in his words about clearing the water. As Mr. Holman indicated, a great proportion of the bacteria go down with the mud in the settling basins. I think, moreover, that the more mud there is left in the water the more bacteria are left in it; so, as nearly as I can find out, it is when our settled water is the muddiest that it contains the most bacteria. The water of the river is worst when the river is rising, when the ground is broken up by the frost and a general washing of the whole country is taking place, bringing down all sorts of impurities from forest lands, etc. Our river picks up the mud and most of its bacteria at the same time and in the same way, and deposits the mud and bacteria at the same time and in the same way. Any method that removes the mud is certain to improve the water, by reducing the number of bacteria in it. I think, therefore, that if we can get clear water it will certainly be pretty good for drinking.

Dr. Charles R. Sanger.—I have never had an opportunity of making a very extended chemical and biological investigation of the Mississippi water, but so far as the practical part is concerned I am fully in accord with Prof. Johnson in what he said about dollars and cents. I think this is most important, and the chief way in which the public are to be reached. But I do not agree with Prof. Johnson in the opinion that the water is wholesome. While we have, it is true, a small death rate in St. Louis, we are not quite free, and not as free as many other cities, from digestive troubles due to bacteria not strictly pathogenic. I think this water is responsible for a great deal of the enteric troubles we have in St. Louis. As to the presence of pathogenic bacteria, I have had in my own family a child sick of typhoid fever, and I am absolutely certain, by excluding every other possible source, that the typhoid fever was due to accidental drinking of unfiltered St. Louis water. I am absolutely certain that the typhoid fever epidemics we have had here have come from St. Louis water.

As to the removal of the bacteria, sedimentation can accomplish this to a large extent, but it does not remove all; and even if the water were also coagulated, that would not remove all of the bacteria. It is absolutely necessary to filter the water, for then alone are we sure that the water is free from bacteria.

The German limit of 100 bacteria per cubic centimeter is very easily reached, and is reached constantly by filters in operation in the East, notably by that at Lawrence, Mass. Mr. Holman has proceeded in his usual conservative way; I think he has done about as he ought to have done, but, of course, filtration cannot come if there is no public demand, and there *is* no public demand in St. Louis for filtration. Almost every one is satisfied to drink the water as it is, or would be satisfied with coagulation, to simply make the water more attractive for drinking; and they would be content by so doing to get rid of most of the bacteria. I should have liked Mr. Holman to call in the assistance of some men in this country who have been making a study of this matter for years. But without their assistance he has proposed what seems to me a very practical plan; which is, as far as I understand it, to make use of these present settling basins, which he has thoroughly under control, for coagulation by aluminum sulphate or any other coagulant which may seem practical; to get the bulk of the matter precipitated out in the basin (and this precipitate can be readily and cheaply removed), and then run the clarified water through the filter. Now for this water something like the Worms system would seem very appropriate, if there was no difficulty in forming the film on the outside of the elements. I am very sorry indeed that Mr. Holman's plan for an experimental filter plant, to filter 50,000 gallons, could not have been adopted, particularly because the city government ought to have a chance to see what he could do on what would be called a somewhat large scale; large enough, if he had been allowed to try it, to show exact results, after which he could go ahead at once on a larger plant. There is no body of men better fitted than the Engineers' Club of St. Louis to urge such a movement as that for the filtration of the St. Louis water, and they should use every effort to bring the matter about.

Mr. B. H. Colby.—I agree with what Dr. Sanger has said about the experimental plant. This was first brought to public attention by an ordinance drawn by the Water Commissioner and sent to the Municipal Assembly by the Board of Public Improvements about two years ago.

It went into a pigeonhole, where other meritorious ordinances for public work have found permanent resting places before, and, as you know, nothing was done. Sometimes it seems almost disheartening to those engineers who are trying to give this city pure water to have their efforts rendered inoperative by the lack of the necessary legislation to carry out their plans. I think the commercial demand would be almost entirely satisfied if our water

were clarified. If we had clear water to wash and bathe in probably not over 5 per cent. of the people would insist upon filtration. To a large proportion of our population *clear* water means *pure* water. Those who know the danger that may be in perfectly clear water will continue to demand filtered water, and that their demands will ultimately secure the filtration of our water I have no doubt whatever. Just when this will be accomplished we cannot at present predict.

Much legislation is necessary before the city can be placed in a situation to supply filtered water to its citizens. After the filter plan is fully completed, it cannot be successfully operated until provision is made for the employment of a corps of competent chemists and bacteriologists. These men should make daily tests of the water passing through each filter. They should live in houses owned by the city and located adjacent to the filters. Their qualifications for their positions should be capability and fitness for the particular work to be done by them. They should hold their positions for life, as should the higher officials in charge of our water works plant. Legislation is needed to accomplish all this, and much more, of which there is not time to speak to-night; but before we can secure the *good* legislation we must rid ourselves of perniciously bad political practices. Our citizens must learn the importance of having their public works in the hands of the best men obtainable.

When this is learned they will demand that only men of the highest attainment and fitness be intrusted with the design, construction and maintenance of our public works. They will go further and demand the separation of public work from all political interference.

When this conception of the conduct of our public work has been bred into the daily thought of our people their action will be quick, the results permanent. Unless the desire for a better order does grow up among our people we will have national degeneration, and our children will see jewelers reporting on our water supply and harness-makers building our filters.

Dr. Glasgow.—I doubt whether it is desirable to limit the amount of water used. If we filter we will have to have meters, limiting the quantity of water. Is that desirable? I have always been of the impression that the more water was used the better the health of the community, even if that water was not as good as it ought to be. The problem in European communities is different from ours. I question, also, whether clearing the water of sediment renders it wholesome, and whether leaving the microbes in the

water is in all cases hurtful. We who have lived along the Mississippi River, and have drunk its water, feel that mud is not so very unhealthful. Dr. Sanger has not lived here long enough to get used to it. He brings his Eastern prejudices with him, and I have no doubt that if he lives here long enough he will appreciate this water more than he now does. Then, again, cases of typhoid will occur in every community. I suppose there is no community on the face of the earth that does not have them. We have some here. If Dr. Moore will look at the statistics of large cities he will find we have less than our proportion. The water here, impure as it is, is better than the clear water they have in other cities; and if we succeed in getting rid of the mud the bacteria will be cast down with it, and we will have the finest water in the world. No water tastes like the Mississippi River water. European communities seek to get rid of bacterial life, while here we seek to get rid of the mud. When that goes the bacterial life goes with it.

Dr. Sanger.—Without seeking to controvert Dr. Glasgow, I want to say I have no prejudice. I lived twelve years of my life away from the East, long enough to be away from Eastern prejudice.

President Bryan.—The objections urged against the reduction of the per capita consumption by the use of meters do not apply, for some minimum charge will be fixed. The charge will be upon a sliding scale, and the minimum fixed at a consumption ample for all reasonable requirements. The idea is to make a distinction between ample consumption of water and absolute waste.

Mr. Moore.—In regard to the claim that the larger the consumption of water per head the better the health of a city, I think it is only necessary to refer to Chicago. The consumption there is about 160 gallons per head per day, or nearly 50 per cent. more than in St. Louis. Yet the typhoid rate of Chicago is double that of St. Louis, and the danger from using the Chicago water is so well known that the daily papers there are constantly urging people not to drink it unless it has been boiled.

Mr. McCulloch.—Does the Mississippi River water, after it has been settled and the mud taken out, contain more than 100 bacteria per cubic centimeter?

Dr. Sanger.—The question can hardly be answered except by experiment. The number of bacteria varies with the condition of the water.

President Bryan.—Would it contain more than that number before it is filtered?

Dr. Sanger.—Of course. Yes, at all times.

President Bryan.—Have there been any regular biological experiments conducted in this city by the Water Department?

Mr. Russell.—While making experiments with mechanical filters we took a few gelatine plates, and the results agreed quite nearly with those obtained elsewhere with mechanical filters. But we kept no biological record of the water from the river or water from the settling basins.

Mr. John C. Trautwine, Jr. (by letter).—On the day following the St. Louis cyclone of 1896, and the annual convention of the American Water Works Association at Indianapolis, I had the pleasure of visiting, for the first time, the city of St. Louis, and, by courtesy of Mr. Holman, and in company with Mr. Russell, the water works at Bissell's Point, Baden and Chain of Rocks, of all of which I had read in editing the series of papers descriptive of the works, published in the Journal of the Association for January, 1895, which included papers on the "History of the Works," by Mr. Holman; on "Points of Interest in the Design and Construction," by Mr. Russell; on the "Quality of the Supply," by Mr. McMath, and on "Filtration," by Mr. Moore.

In the annual report of the Philadelphia Bureau of Water for 1895 I quoted freely from Mr. Moore's paper, and reproduced some of his diagrams. In editing Mr. Holman's present paper, therefore, I found myself irresistibly tempted to ask permission to contribute my mite to the discussion.

The first effect of reading Mr. Holman's paper is to deepen my sense of the difficulty confronting the engineer approaching and studying the problem of filtration of municipal water supplies. Not only is the problem in each city distinct from all others, but we are confronted also with startling divergence of views on the part of the doctors of sanitation.

Mr. Holman, recently returned from a visit to the German filter plants, naturally comes highly charged with the doctrine of the efficacy of the bacterial jelly, and informs us that the German experts have scarcely even heard of nitrification. This reminds me that, in conversation with so eminent an expert as Mr. Hiram S. Mills, of Lawrence, Mass., the apostle of intermittent as distinguished from continuous filtration, that gentleman expressed the opinion that the German view of the importance of the bacterial film was without foundation, and that nitrification was the one thing needful. Indeed, I have recently heard that a noted expert in bacteriology has declared that the bacteria in water are of very little consequence.

I am surprised by Mr. Holman's statement that the bacteriological results of so-called mechanical filtration have not as yet been carefully investigated; for, in 1896, Mr. Edmund B. Weston published, as an appendix to the "Seventeenth Report of the State Board of Health of Rhode Island, for the year ending December 31, 1894," a series of tables giving the results of a very elaborate series of experiments with a small Morison mechanical filter at the Pettaconset pumping station at Providence. Elaborate experiments are now being made with a Warren and a Jewell filter in comparison with an open sand filter and Fischer sand plates at Pittsburg, Pa., and the water works public is still waiting for the

results which are one day to emanate from the Louisville experimental plant.

While there is some similarity between the filtration of water through sand and the reverse operation of filtering sand or mud through water, I am hardly ready to say, with Professor Johnson, that "there is no difference" between them. It would appear that when water filters through sand, its particles come into far more intimate and effective contact with the solid particles than during the reverse operation of filtering sand or mud through water. From experiments made a couple of years ago in the Bureau of Water at Philadelphia, it appears that sedimentation, within such limits of time as are usually permissible, is far less effective than filtration in the removal of bacteria. Philadelphia water, however, even at its worst, can hardly be said to compete successfully with that of St. Louis in the matter of sediment.

I regret that Mr. Russell has not given us some idea as to the results obtained with upward filtration under Colonel Flad. If, as Mr. Mills declares, the bacterial film is of little account, we might expect good results from upward filtration, in which that film has little chance to form, and in which the sediment falls away from, and not upon, the bed, and in which the cleaning is effected by simply reversing the current, sending it downward through the bed. Cleaning may thus be readily effected under ice, so that the difficulty of cleaning the filter in winter, or the necessity of providing a roof for it, may be obviated.

Philadelphia now consumes about 200 gallons of water per head per day, and a total quantity equal to that consumed by the four-fold greater population of London. Naturally, therefore, I am much interested in the discussion on the questions of waste and of meters, especially in Mr. Russell's estimate that the cost of a filtered supply, properly limited by meters, is less than that of an unfiltered supply where waste is allowed to proceed unchecked. This may well be the case where, as in Philadelphia, restriction of waste may mean avoiding the necessity of constructing an entirely new and very expensive system of water supply.

I am heartily in accord with Dr. Glasgow in advocating the free use of water. All that we aim to control is its *waste*, which either inflicts unnecessary burdens upon the community or deprives careful people of a full supply in order that the reckless and unscrupulous may throw water into the sewers without its accomplishing any good whatever. Mr. Pitzman's contention that water wasted into the sewers does not flush them is, I believe, entirely correct.

In Philadelphia, as in other places, we seek to prevent undue restriction in the consumption of water by fixing a minimum charge, as mentioned by Mr. Bryan. This charge is about one-half the regular schedule rate, and consumers save nothing by keeping their consumption below that point.

Until recently I was disposed to endorse Mr. McMath's view that every supply should be metered; but a recent experiment, in which, for our information, we placed meters upon some twenty dwelling houses, showed that all but three or four of these were using water quite reasonably, so that it would have been a mere waste of money to meter them. To meter every supply in Philadelphia would cost the city some four million dollars, whereas, if it were found necessary to meter only say one-fifth of the whole number, the cost would be proportionately reduced.

Fig. 1.

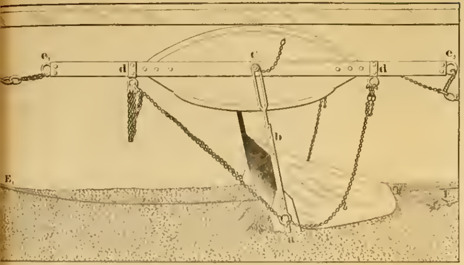


Fig. 2.

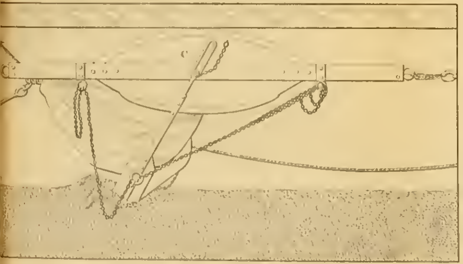
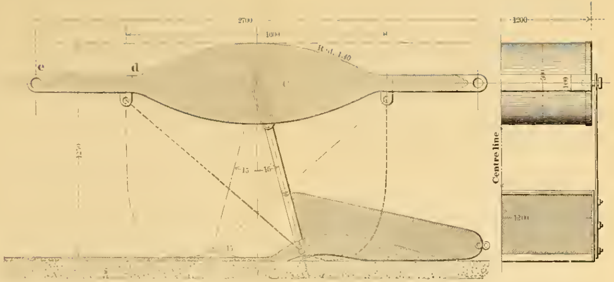


Fig. 2a.



Figs 1, 2 and 2a Apparatus for scraping filter bed under ice (Hamburg)

Fig. 3

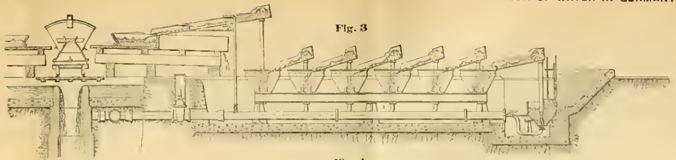
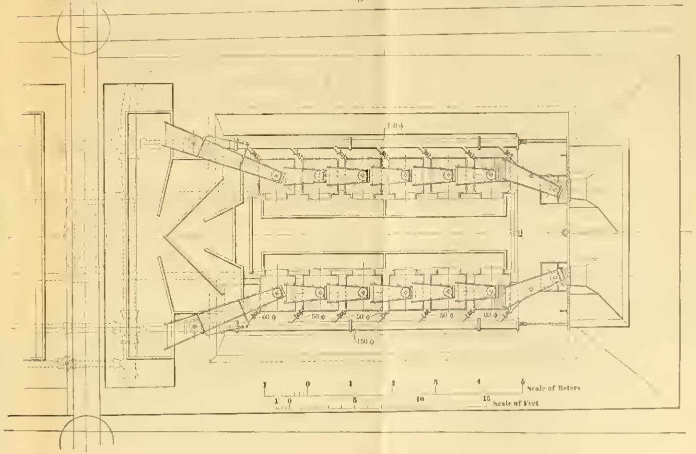


Fig. 4



Figs. 3 and 4. Apparatus for cleaning sand removed from filter beds (Hamburg)

Mr. Pitzman's mention of the relations between St. Louis and Chicago, in the matter of stream pollution, calls forcibly to mind the position at Philadelphia, which, if it appeals to the State Board of Health for protection from pollution of the rivers above it, is apt to be met with the charge, only too well founded, that Philadelphia sends most of its sewage through the Delaware to the towns below.

Noting Mr. Holman's reference to double filtration, in which the water is passed through two successive filter beds, I am reminded that Mr. Halbertsma, engineer of water works at the Hague, in Holland, advised me recently of some experiments of his in that line. I have not the exact figures at hand, but my recollection is that the first filtration removed nearly all of the bacteria, leaving little for the second filtration to do. On the other hand, Mr. Halbertsma wrote me, in April, 1897, that double filtration at Schiedam was "quite a success," and that he was designing other works on the same system.

At Reading, Pa., is a two-story sewage filtration plant, where the sewage, after passing through a bed of coke at the receiving station, and then through a long conduit, falls upon an upper bed of sand 18 inches in depth; after passing through which, and falling 10 feet through the air, it passes through a second sand bed 3 feet deep. Each of the sand beds rests upon a 6-inch layer of broken stone, and the lower bed is covered with 2 inches of small stone, in order to protect its surface from the abrasion of the falling liquid.

The Pennsylvania Sanitation Company, which built the plant, publishes the following results:

PERCENTAGE OF BACTERIA REMOVED.

After passing.	Oct. 9, 1896.	Oct. 19, 1896.
Coke	29.68	66.83
Upper bed	98.11	99.54
Air	99.54	99.84
Lower bed	99.92	99.9996

Noting, in Mr. Holman's paper, that previous filtration deprives the water of its power of forming the necessary film on the second bed, and that prior sedimentation also interferes with the formation of this film, I am moved to ask what has been the experience, in this respect, in London, Hamburg and other cities where sedimentation takes place before the water passes to the filter bed.

It is rather remarkable that the cleaning of the bed in Hamburg, by the machine which Mr. Holman describes, should, by packing the sand, reduce the relative output, whereas cleaning in general naturally increases the rate. Cannot this difficulty be obviated by a rake or harrow following the machine?

Note by Mr. Holman. At Hamburg the action of the clay and sand, in the sedimentation basins, is not sufficient to drag down enough of the bacteria to prevent the subsequent formation of the film on the filter beds.

NOTES ON THE MATHEMATICAL THEORY OF NAVAL ARCHITECTURE.

By Joseph R. Oldham, N.A., Member of the Civil Engineers' Club of Cleveland.

[Read before the Club, May 24, 1898.*]

On Wednesday, July 7, 1897, a grand dinner was served in the Kings Hall, when the First Lord of the Admiralty made a clever and humorous speech, in the course of which he said that when the low freeboard turret ship "Devastation" was completed his numerous technical advisers placed him in a dilemma, many eminent naval experts having told him that if he allowed that warship to proceed to sea he would be guilty of murder, while other no less eminent and equally numerous authorities on naval affairs assured him that he would be sacrificing the prestige of the British Navy if he did not send her to sea.

His position for the moment was by no means an irresponsible one. She went to sea, however, and he has not been formally accused of breaking the sixth commandment, and, from all he could learn, the prestige of the British Navy is not seriously impaired.

Mr. Goschen added that, in addressing so representative a gathering of distinguished naval experts, he must sincerely compliment them on their marvelous achievements, but he had to tell them of one thing in connection with naval architecture they could not do; it was a miserable little physical defect they had never mastered—they had not yet designed a vessel to prevent sea-sickness.

Perhaps Mr. Goschen had Sir. Edward J. Reed in mind when he made this latter remark, for, if I am not mistaken, it was no less a personage than the ex-Chief Constructor of the British Navy who, when the writer was a boy, designed a large passenger steamer with suspended or swinging cabins to prevent *mal de mer*. I think this scheme proved anything but a success; however, the Welsh proverb teaches us that "failures are the pillars of success." And in his case the proverb proved literally true, for to-day there is not a naval architect more highly thought of than the same Sir Edward. It may be true that his early reputation as a cautious chief constructor was somewhat tarnished by his supposed responsibility in connection with the design, or perhaps I should say in connection with the commissioning, of the ill-fated "Captain."

*Manuscript received June 9, 1898.—Secretary, Ass'n of Eng. Socs.

But be that as it may, his services to the body of naval architects and shipbuilders of the wide world have been liberal and grand in the extreme. As an author, his language is dignified and convincing; his illustrations are clear, concise and correct; his imagination is superb; he exalts hard and dry subjects into the region of romance. As a writer upon the science of naval architecture he compares not unfavorably with Scott as a novelist or historian.

There are many elegant writers among the naval architects, such as Elgar, White, Barnaby, Martell, Gray, Milton, but none, I verily believe, so justly popular as Sir Edward, and none more honorable. His clear, sensitive mind appears ever on the alert lest he should inadvertently assume to himself the productions of another, or fail to award due credit where credit might be due. What I am trying to convey will be better understood after reading the preface to his exhaustive work on the "Stability of Ships."

The literary event of the congress was undoubtedly the reading of the paper by Sir Edward J. Reed, on the "Advances Made in the Mathematical Theory of Naval Architecture During the Existence of the Institution." Referring to the longitudinal strength of ships, he quoted from a paper by the late Mr. John, showing that in a vessel over 400 feet long the maximum tension was found to be 8.85 tons. These forces were not sufficient in themselves to cause rupture in a vessel well built of good materials, but they might be sufficient to cause very considerable straining, which, if not attended to in time, must weaken the vessel to the point of danger. With reference to the transverse strains of iron merchant vessels in docking them, he mentioned the case of a vessel supported by the keel alone, and with only breast shores to keep her upright; and demonstrated the need of great transverse strength, especially in the engine and boiler space, where the localized weights of the machinery increased the strain at the middle line and the bilge.

In the all too brief discussion which ensued, the writer of the present article pointed out the improved system of docking practiced on the American lakes, where the bilge blocks are drawn under the vessel before the water is pumped out of the dock; and he asked Sir Edward whether the absence of this bilge support in their system would not account for some of the straining observable at the bilges and bottom of broad ocean steamers, which were sometimes placed in dry dock resting on the keel blocks only, and with the coal bunkers in various stages of fullness, and added that the bilge and bottom butts of lake steamers were seldom found in

as bad condition as ocean vessels. It should not be supposed that the immunity from such straining in lake steamers can be accounted for by want of hard work or by shortness of service, for we have some very old iron vessels. Indeed, he believed that the oldest iron steamer in active service in the world was now afloat on the American lakes.

In the paper mentioned, Sir Edward said:

"At a conference of naval architects, held a few weeks ago in London, I drew attention to the remarkable nearness that exists between the strengths of ships and the estimated strains at sea to which they are subjected, pointing out that shipbuilding practice presents us with no such large "factors of safety" as we all require in bridges and other land constructions. Sir William White and other speakers truly pointed out that practical experience has made it certain that no such large factors of safety are really requisite in ships. But it seems equally certain that no one can say at present what the factor should be, even as regards longitudinal strength, and its determination is one of the results to which we may confidently look forward."

Speaking of the metacentre, Sir Edward said:

"Of late years some persons have fallen into the habit of calling a large number of points, not in the vertical center line of the ship, metacentres. This is a mistake, and in dealing with ship calculations nothing should be called a metacentre that was not situated in the original upright axis of the ship. In other words, there is but one metacentre,—viz. that due to a slight inclination from the upright where the vertical through the center of buoyancy intersects the original center line of the ship in her upright position."

It was pointed out that Prof. Ocborn Reynolds took serious objection to the confusing use made of the word "stability." He said:

"In recent literature on naval architecture the term stability occurs over and over again in the sense of righting moment, and this under circumstances where the context shows the meaning to be incompatible with any meaning that can be given to the word, for stability must refer to some position in which the ship is stable;"

and he went on to develop this objection at some length, particularly pointing out that

"the righting moment exerted by the buoyancy at considerable angles of inclination is often found to be effective, not in restoring the body to an upright position, but merely in restoring it to some other less inclined position, in which it will remain if left free to do so. The truth of this is well known to most naval architects, but it may be well to give the curve of stability of an actual ship illustrating the case by Fig. 1. This ship has a negative metacentric height of 6 inches, and she lolls over 20° before she begins to acquire an opposing moment. From 20° to nearly 80° she has a righting moment of precisely the same kind as an ordinary ship; but this moment only returns her toward and not to the upright position. Again, when we speak of righting levers and righting moments (which are but conditional measures of rotating forces) as identical with or equivalent to

stability, we reach the anomalous position of having, even in a ship of very great stability, in the popular sense of the term, no stability at all when she is upright, or, as in the case just illustrated, none at all when she lies free and at rest at 20° of inclination."

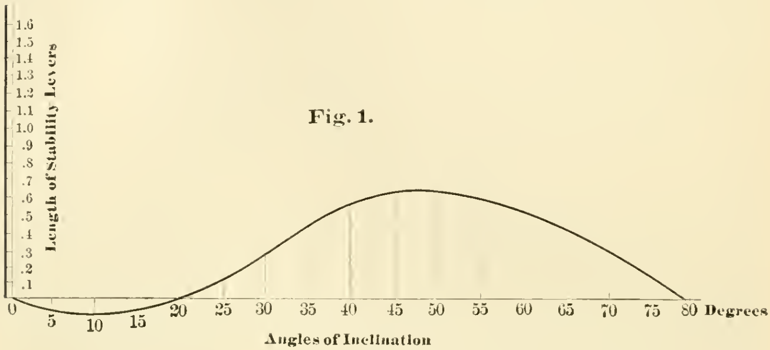


Fig. 1.

With reference to the loss of the "Captain," a criticism of Sir Edward's paper (1868) said:

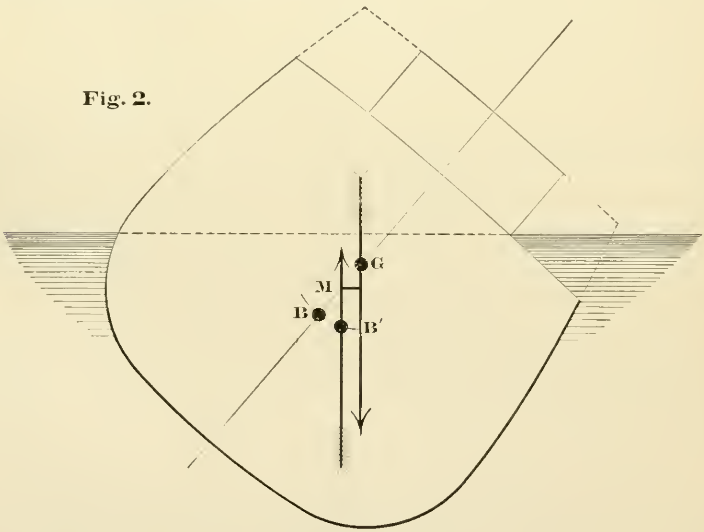
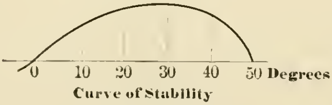


Fig. 2.

Fig. 3.



"It showed conclusively that instability would occur in such (low freeboard) vessels at a very moderate angle of inclination, and illustrated the contrast, as regards stability and safety, existing between rigged ships with high freeboard and those with low freeboard. . . . This paper did not succeed, however, in impressing members of the profession with the neces-

sity for more complete calculations of stability, and the subject remained in comparative obscurity until the loss of the 'Captain' forced it into painful prominence."

The "Captain," it may be remembered, was a low freeboard ship, and might be compared in that respect to a deeply laden merchantman, such as the "Marlborough," which also capsized. See Fig. 2 as an approximate illustration of that disaster.

Sir Edward then referred to a *light* vessel, and said:

"It unhappily required a further incident and another calamity to open men's eyes to the very opposite danger,—viz, that of ships capsizing at light draft. In 1883 the 'Daphne' capsized on the Clyde during launching, and I was sent down by the Government to inquire and report upon the accident. The inquiry developed several facts which showed how much need there was for large extensions of stability calculations. It proved that ships of modern type are sometimes characterized when floating light by very abnormal deficiencies of stability in inclined positions. The 'Daphne' herself possessed not only small stability, but a slow growth of it with increase of inclination. No curve of stability at the launching draft had at that time been calculated for any ship. Sufficient *initial* stability had been always regarded in ordinary ships as a guarantee of sufficient stability at all angles. Even the highest of our authorities at home had assumed this to be the case. All this proved, however, to be quite erroneous."

As to ballasting of merchant vessels, the author said:

"The use of water as ballast for merchant ships is, I fear, leading to some danger and loss, not because of any inherent defect in its use for this purpose, but because in applying it to the various objects of ballasting, trimming and replacing fuel that has been consumed more knowledge is required than is sometimes available, and more water ballast is needed than is sometimes arranged for. This, however, points not to defective scientific theory, but only to the desirability of extending scientific information."

Suppose a steamer is required to cross the ocean in ballast, where head winds and rough seas may be encountered all the way. It is a matter of great importance that the severe rolling qualities should be reduced to a minimum. To accomplish this the righting levers must not be too long or the moments too great.

In broad vessels the weights carried, such as water ballast, should not be too low down, or uneasy and jerky rolling will result. To obviate this our friends across the ocean have recently invented some ingenious devices. One design is to carry water ballast in the bilges and wings under the upper deck. This arrangement also makes a safe hold for carrying grain without trimming, but, as the flat of the bottom is thus left without an upper bottom, it certainly does not commend itself for our lake trade; moreover, a part of the design is by no means novel. Another arrangement for carrying water ballast appears to me preferable, but I fear the

expense of construction would check its adoption on these lakes, though by such an arrangement an ore carrier might have a very small register tonnage in proportion to dead weight carried.

The error of Scott Russel as to ship resistance, in which he assumed that a ship had to excavate the water or raise it from its center of buoyancy to the surface, was touched upon, and, though this was an extravagant conception of the fundamental work to be executed by the propelling engines, it is certainly true that from point to point the ship has to place itself where the water has just been.

"It is a point worth noticing here what an exceedingly small force, after all, is the resistance of a ship compared with the apparent magnitude of the phenomena involved. Scarcely any one, I imagine, seeing, for instance, the new frigate 'Shah' steaming at full speed would be inclined, at first sight, to credit, what is nevertheless the fact, that the whole propulsive force necessary to produce that apparently tremendous effect is only twenty-seven tons; in fact, less than one-two-hundredths part of the weight of the vessel."

The most striking feature observed in connection with the practical investigations of the International Congress was the many large and powerful battleships building for the Japanese Navy. I will briefly describe one that I examined at the Thames Iron Works and Shipbuilding Company:

The "Shikishima" is 400 feet x 75½ feet, and at 27¼ feet load draft she displaces 14,850 gross tons of salt water, or a little over 16,000 net tons of fresh water, as we usually quote on these lakes. She is to steam at the rate of 18 knots per hour, with 14,500 indicated horse-power.

It is claimed by the builders that the "Shikishima" is the most powerful battleship afloat, being completely armored from stem to stern, from 5½ feet below the water line to 9¼ feet above, with the most modern nickel steel carburetted armor, varying in thickness from 9½ inches to 4 inches on the stem. She is fitted with Belleville boilers.

A Russian engineer, writing about his experience with Belleville boilers, says there were twenty-four on board their steamer, placed back to back with furnaces athwart ships. The steamer had a list to starboard of 10½°. This list caused the tubes of the port boilers to be nearly all bent downwards, and, thirteen of them being out of line as much as one to one and a half inches, were replaced. The uptakes were overheated through too heavy fires being kept up. The labor necessary to keep these boilers in working order was very heavy, and the average consumption of Welsh coal was

from 2.15 to 2.20 pounds per indicated horse-power per hour. These boilers were not fitted with economizers.

The advantages of supplying the boiler with feed-water approximating in temperature to that of the boiler has long been recognized. Its beneficial effects, as regards boiler preservation and reduction of racking stresses, due to variations of pressure, are well established. Even when the heating steam is taken from the boiler direct, so that theoretically there is neither a gain nor a loss of heat by the process, large numbers of vessels in which such feed-heaters are fitted report an appreciable gain (some claim 10 per cent.) in economy, and that when using the feed-heaters steam is more easily maintained than when they are not in use.

When the heating steam is taken from the last receiver of the engine, or the exhaust steam of any engine, a gain in economy can be clearly shown to exist theoretically in some cases as high as 16 per cent. Feed-water heaters are now being fitted in large numbers of vessels of the mercantile marine, and the results obtained justify their adoption.

As there is economy in generating steam at a pressure of 300 pounds, and admitting it to a quadruple expansion engine at a reduced pressure of 250 pounds per square inch, it would seem that the future general adoption of a water tube boiler with economizers is assured, and in the near future their consumption of fuel may be lowered to equal the Scotch boiler.

Sir John Durston shows that with economizers fitted to the Belleville boilers in the cruiser "Diadem," during a trial of thirty consecutive hours, when 12,813 horse-power was realized, the consumption of coal equalled 1.59 pounds per indicated horse-power per hour. This is nearly as low as in the fire-tube boilers.

The armament of the "Shikishima" consists generally of four 12-inch, fourteen 6-inch and thirty-two smaller guns. The ballistic data of the 12-inch guns is about as follows: Weight of projectile, 1000 pounds; initial velocity, 2234 feet; energy, 34,728 tons; perforating power, 25-inch steel.

The "Alabama," of our navy, and battleships of her class, are 368 feet x 72½ feet, and 11,525 tons displacement at 23½ feet draft of water.

Though these battleships are about 25 per cent. smaller than the Japanese or the large English ships, they may not prove to be at all less formidable fighting machines, as they will be more handy vessels and less liable to be held up by grounding. Moreover, though the guns of the main batteries are the same in num-

ber, our ships have four 13-inch guns, as against their four 12-inch, so that their perforating power should be about 20 per cent. greater than that of the foreign battleships.

The American cruisers engaged at Manila were armed only with 8 or $8\frac{1}{4}$-inch guns. Though these are much lighter than the big guns on our *battleships*, you will gather from the following that the $8\frac{1}{4}$-inch gun is a very formidable weapon.

Ballistic data of an $8\frac{1}{4}$-inch gun: Weight of projectile, 238 pounds; charge in pounds, 52; initial velocity in feet, 2336; energy in tons, 9012; range at elevation of 250°, 14,436 yards; perforating power through steel at 1100 yards, $15\frac{1}{2}$ inches; length of gun, 24 feet; weight of gun, 14 tons.

American courage and skill at Manila would no doubt have secured a victory with very inferior ships, yet not without great loss of life and tonnage; but now it is clearly demonstrated that our ships were designed, constructed and armed so as to do great execution without ordinary exposure of the men to the destructive missiles of the enemy. These are ideal conditions in warship designs, yet they seem to exist to perfection in our new navy. But what we require in the immediate future is a number of larger armored cruisers with largely augmented fuel capacity. Only last month, in addition to the enormous government tonnage already building, the British Government contracted for four armored cruisers 440 feet long, $69\frac{1}{2}$ feet broad and of 12,000 tons displacement at $26\frac{1}{4}$ feet draft; indicated horse-power 21,000, and speed not less than 21 knots. These are about 20 per cent. larger than our largest cruisers, but I trust that they may not very long be so.

The Spaniards do not make practical engineers. For several years I was assistant to the chief engineer of three lines of Spanish steamers, and, though all the officers and crew were Spaniards, the whole engine department was managed and worked by British engineers; and, as people of that nationality are certainly not loved by the Spaniards, it may be accepted as proof positive that the Spaniards were incapable of managing their own machinery, or they would never pay Scotch engineers two or three times as much salary as Spaniards would readily work for.

The incapacity of the Spaniards to stand up for any length of time before our ships is largely due to their ignorance and inefficiency as engineers. A modern battleship or large cruiser is nothing less than a complicated piece of machinery from keel to truck, in hull, armament and equipment. Imagine a hundred steam cylinders requiring half as much steam as the main engines to be kept in working order, besides numerous hydraulic and

electrical appliances, and you may acquire an idea of the mechanical skill necessary to keep a modern battleship in fighting condition.

Now there are plenty of grateful people in our community to praise the splendid gallantry of the commanders and sailors of our warships, but there is a class of men who are not so much seen on deck or on boarding expeditions, and whose names but seldom appear in the papers or in dispatches, but who, nevertheless, are doing as brave and noble a work as their weatherbeaten comrades of the bridge and deck. I refer, of course, to the engineers and their staff, and I may say, for I know it from personal acquaintance, that a finer class of men than our naval engineers are not to be found in any country. Many of them are good mathematicians as well as practical mechanics, and all are gentlemen; but engineers are not always treated as if they were. Sailors call them "the Black Squad," or "Sanguinary Blacksmiths," and I well remember the time, in the old country, when a great government marine department was always managed and under the control of a retired shipmaster, though the work to be performed was almost solely of a marine engineering character.

It was only a very few years ago that the position of principal officer was conferred by the British Government on George Carlisle, a marine engineer. Prior to that appointment the condition of engines, boilers, etc., on large steamers had to be approved and certified by a retired shipmaster. During the present struggle, while we "remember the Maine," let us not forget those brave men who keep up steam and work the machinery in the quietest manner possible, away from the glare of the sunshine and the ear of the scribe.

We are now on the last verge of a period rapidly vanishing away, and upon the brink of another period just as rapidly approaching. The present time is bristling with momentous possibilities, and it behooves us to give most earnest attention and thought to the opportunities now presenting themselves. It may be that the very existence of the Anglo-Saxon race, as a political factor in the economy of nations, is at stake. We cannot recede, "There is a tide in the affairs of men, which, taken at the flood, leads on to fortune." We are bound to go on with this righteous struggle, though it may have surprised some and though it disappoints others. The builder of our first monitors thought he had discovered the panacea for peace. Thirty-three years ago, John Ericsson said: "The art of war, as I have always contended, is positively in its infancy; when perfected man will be forced to live

in peace with men. This glorious result, which has been the cherished dream of my life, will unquestionably be attained before the close of the present century."

The century is drawing to a close. Let us hope that Ericsson may prove a true prophet even yet, but his dream seems exceedingly far from realization.

It would now seem that we are more than likely to become an Oriental power, and we are also extending our possessions far South; but these possessions must be paid for, and a large item in the payment will be lives of our people. This is a new doctrine, of striking and vital import. What a marvelous change has come over us during the last few weeks. How different, in its tendency at least, from the celebrated "Monroe Doctrine;" strange that this was not foreseen! As we gain in resources we gain in power; as we gain in power we gain in influence, and our influence in the future must be important and far-reaching indeed. If the mechanical sciences and naval architecture arts of seventy-five years ago had stood still like "Joshua's moon in Ajalon" we might have remained in happy isolation from the sphere of European or Oriental influences, secure in the spirit of the Monroe Doctrine; but, with the advent of the screw steamer, the electric cable and the locomotive, space and time are annihilated and the nations farthest apart geographically are in closer touch to-day than England and Spain were in Monroe's day. In 1823, when that brilliant statesman enunciated his famous views of "hands off," or "America for Americans," there was not a screw steamer or a surface condenser on the ocean. Our total ship tonnage was less than one and a half million tons, the population of these United States was only eleven millions. To-day our population is nearly seventy-five millions, and our ships amount practically to five million tons. When one can leave the center of England on one Saturday and take midday lunch in Cleveland, Ohio, on the following Saturday, as I did last year, it may be truly said that "the seas but join the nations they divide."

How some of our prominent legislators, even a few months since, could talk of this free and most powerful nation continuing an isolated political existence with regard to the other great nations of the earth seems strange indeed, and I think that happy state is a condition of the past. If this is so, might it not be to our mutual advantage if an alliance could be cemented between the great Anglo-Saxon peoples, both far and nigh?

I think the people who have possession of Hong Kong, Australia, Gibraltar, Malta, Alexandria, Aden, Bermuda, Victoria

and a few other small possessions, such as India, Canada and South Africa, and which, politically and socially, are practically as free as any nation upon earth, should be worthy of an alliance with this great, glorious and all-powerful republic.

DISCUSSION.

Mr. H. C. Thompson.—What is your opinion as to the relative values of the monitor and battleship as fighting machines.

Mr. Oldham.—The distinguishing features of the monitor are that, requiring less steam radius, the armor can be heavier and the freeboard lower, so as not to present so large a target to the enemy. A battleship is higher, so as to be defensive against any weather, and its large coal capacity enables it to steam longer distances.

Mr. John N. Coffin.—Has the theory of raising the water ballast above the gravity center been tested sufficiently to prove that the rolling is lessened thereby?

Mr. Oldham.—The object of the design is to lessen the stability by lessening the righting moment. This is accomplished by raising the center of gravity to the metacentre, and so reducing the lever arm. The longer the righting lever the greater the moment to lift the vessel; and when she is lifted from one side she accumulates energy, passes the center and rolls to the other side, and then reaction follows. With less righting moment the reaction is less violent.

Mr. W. C. Parmley.—At the present time we are all interested in battleships, and in the question not only of the efficiency of those we possess, but also of the correctness of the lines of our progress in the design of new battleships. The British Government, since 1890, has built about thirty first-class battleships. The earlier of these ships, of the "Royal Sovereign" type, were armed with 67-ton (13.5-inch) guns, were armored with 18-inch steel and had a speed of 16 knots. The ships of the "Majestic" and "Prince George" class, built about 1895, carry four 12-inch guns and 14-inch armor. The latest warships have decreased the armor to 12 inches and carry four 12-inch guns, with very heavy secondary and lighter batteries.

Our vessels started in with 13-inch and 8-inch guns, and with 18-inch armor. We have retained the 13-inch gun as the standard size for the primary battery, and retained an armor thickness of 16½ inches. In addition, we carry about the same number of rapid-fire guns as the latest British ships. The British ships are slightly faster than ours, and are of about one-third larger tonnage. Are

the British right in thus reducing the diameter of the heavy guns and the thickness of armor, or are we right in retaining the great weight and power of both?

Mr. Oldham.—The main difference is that the British vessels have greater coaling capacity than our ships, and their extra displacement is largely taken up in supporting the coal. I think the turret is a better protection for the gunner than the barbette, but there is more danger of its getting out of order. The steel of to-day is far stronger than that of a number of years ago. After a time we can abandon iron armor altogether, making the vessels in water-tight compartments and allowing the guns to go through them. By that means we can build two boats for every one, or three for two at least. All these questions rest very largely on a money basis. The British are now building ships because they have plenty of money. When hard times come the people will not stand it, and the work will have to stop.

Mr. Parmley.—What is your opinion of the relative fighting qualities of our "Alabama" class and the most formidable foreign vessels?

Mr. Oldham.—The most formidable foreign vessels have not yet been tried. I think we have the best fighting ships in the world. I think our ships, especially with a Dewey in command, could stand up against any of the British ships.

Mr. Searles.—We find ourselves very unexpectedly in the midst of foreign war. It hardly seemed credible at one time that it should be so, and yet the most momentous results may grow out of this condition. It seems to me the coming of age of this nation. We have been a lot of bright Yankee boys before, and now we are to take our part in the affairs of the world, which must be managed by some one. We must abandon our isolation, not from the spirit of ambition or vainglory, or the coveting of additional territory, but as a man coming of age must take part in the affairs of the world, so this nation must take part in the affairs around it. This throws the Monroe Doctrine to the winds, but it may become our national duty and privilege to assist in the direction of international questions.

In regard to the relative value of ships and armaments, it is my impression that more depends upon the men behind the gun than upon the gun itself. It is the discipline and spirit of the crew, rather than the amount of protection or the diameter of the bore. This naval conflict is a machine war, and it is not the best machines, but those operated by the best machinists and engineers, which are likely to win. On that account I feel very great confidence in the

ultimate success of our own arms. The Spaniard has very little genius for machinery, however great his personal bravery may be.

Mr. A. L. Hyde.—Our battleships and cruisers have been recently constructed, and yet we are constantly reading that they are smaller and carry less tons than those of other nations. Are our ships really less formidable, and, if so, why so? Is it a fact that our naval engineers have considered that smaller and speedier vessels are more formidable than some of the larger vessels? If we were to have a war with some other nation whose men behind the guns were the equals of our own, the contest would be decided by the superiority of the armor or of the guns.

Mr. Oldham.—The larger vessels will certainly be the more formidable, if they are as well constructed, designed and manned. The principal point is that the larger vessel can carry a larger supply of coal. I think our ships cost 30 per cent. more than British ships to construct. The question of dimensions is entirely an experimental one, and Sampson may have tried the experiment lately. The whole question of the formidability of battleships is yet to be solved.

Again, westerly winds prevail here, and we have not the heavy seas that they have on the other side of the Atlantic, so that we can get along with a lower freeboard. The British vessels must have height in order to get away from the waves, and I think that is the main reason that their vessels are larger.

Mr. Parmley.—How do you explain this fact: since 1890 the British have reduced the size of their most formidable guns from 13 to 12 inches, and the thickness of their armor from 18 to 12 inches, while we have kept our armament up to about 13 inches?

Mr. Oldham.—They have reduced the bore because they know that a shot from a 12-inch gun will go through any armor that exists.

Mr. Parmley.—Why should they decrease the thickness of the armor?

Mr. Oldham.—Because the steel is far stronger than it was.

Mr. Parmley.—Then why should we keep it up?

Mr. Oldham.—Because we have to carry less coal, and can put the weight into the sides of the vessel. I think you will find that we shall be building battleships of 15,000 tons. The tendency is toward lighter armor and greater speed. I think the armor is not of so much importance; Dewey has not an armored ship with him.

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ABOLITION OF THE GRADE CROSSINGS ON THE MAIN LINE OF THE BOSTON & ALBANY RAILROAD IN NEWTON, MASS.

BY IRVING T. FARNHAM, WILLIAM PARKER AND W. G. S. CHAMBERLAIN. MEMBERS OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Society, February 16, 1898.*]

I. History of the Improvement, and an Account of the Street and Drainage Work Connected Therewith.

BY IRVING T. FARNHAM.

FOR several years the abolition of the grade crossings in the city of Newton has been a subject of agitation among the citizens and taxpayers. The city covers a large area in proportion to its population, and consequently has an unusual mileage of railroad, mostly controlled by the Boston and Albany Railroad corporation. The four tracks of this road extend through the city from the village of Newton to Riverside, a distance of 4.4 miles. At Riverside two tracks branch to the south, returning to Boston through Eliot, Waban, Newton Highlands, Newton Centre and Chestnut Hill, making altogether 1 mile of single, 6 miles of double track road and 4.4 miles with four tracks.

Only the crossings on the north side of the city on the main line have been abolished. There were thirteen of these, two of which were private streets, but were provided for with the rest; and

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two (St. James street and Bellevue street) already crossed on overhead bridges, but had to be changed to fit the new conditions of grade. The city has also built four new streets, crossing the railroad, making a total of seventeen crossings, one having been discontinued.

The two north tracks of the railroad are used for the through traffic, while the south tracks are for suburban travel. At each of the stations of Newton and Newtonville there was a grade crossing, while at West Newton Station there were two grade crossings in close proximity to the station. Persons hurrying to and from the suburban trains were in constant danger from the expresses on the north tracks, and the greatest care of gate tenders could not avert disaster. There seemed to be no question of the necessity of separating the railroad and street grades, but how it could be accomplished to give the best results, both for the city and the railroad, was the problem. No expense was spared to give the matter a thorough study, both as to its engineering and economic features.

The State Commission of Engineers, appointed in 1888 to report upon the "gradual abolition of the crossings of highways by railroads at grade," with suggestions and recommendations as to the best method of accomplishing such abolition, reported in 1889 upon the crossings in Newton and other cities, and recommended a plan for abolishing the crossings by depressing the tracks from east of St. James street to a point between Mt. Vernon street and Greenwood avenue, and elevating the remaining distance to Auburn street, Auburndale, carrying the streets over and under in each case. Their plan did not, of course, go much into detail, except to establish a proposed grade shown on a profile with the report. On this profile is also marked a grade for depressing the track the entire distance, which was proposed by our esteemed associate, the late Mr. Noyes, who was then City Engineer. This plan called for a large change in the railroad grade, with slight changes in the streets, and seemed too bold to meet the approval of the commission. To quote from their report: "By Mr. Noyes's plan, the principal work in separating the grades will be on the railroad. Only a few unimportant changes are proposed in the streets. The question of proper drainage for a long railroad cut, as proposed by this plan, is one that should be carefully considered. To sink the railroad to a depth recommended will not only be expensive, but there is also an uncertainty, in our opinion, as to the results that will be obtained from the system of drainage recommended. The question of proper drainage for a railroad of such magnitude as the Boston and Albany is a matter of vital import-

ance, and a plan should be selected that would secure it beyond a doubt." Other seemingly good objections to this plan raised by the commissioners were the extra expense, the delay in traffic and the heavy rock-cutting that would be encountered. Most of these difficulties, however, as will be shown, were avoided in the final plan for depressing the tracks.

In 1892 a commission of engineers, consisting of Messrs. Albert F. Noyes, City Engineer, George S. Rice and Charles A. Allen, all members of this Society, was appointed by the city government to make plans, with estimate of cost, for the abolition of the grade crossings. First, by depressing the tracks and elevating the streets; second, by elevating the tracks and depressing the streets; third and fourth, by carrying the railroad north on a new location, through a less thickly populated district. This commission reported in May, 1893, recommending that the tracks be elevated on the present location. The relocation through a different section of the city was discarded as impracticable, because of the radical changes in property valuation which would result. This could not be estimated in dollars and cents, but would undoubtedly work great hardship and severe loss in the one case, while it would immediately benefit land-owners in other cases.

After the receipt of this report hearings were given by the city government for the expression of public opinion upon the plan of action. Notwithstanding the report, the general feeling seemed to be in opposition to a railroad embankment through the city, and, as the railroad officials were not ready to co-operate with the city for depressing the tracks under the existing laws, it was decided to defer the improvement until more favorable legislation could be obtained.

Washington street is the main highway through the north part of Newton, and runs parallel with and in close proximity to the railroad from Newton to West Newton, 2¼ miles. It is the main thoroughfare between Wellesley and Weston, on the west, and Watertown, Cambridge and Boston on the east, and for some time there had been a demand for widening this street. The width of the old street varied from 37 to 60 feet, and both sides were closely built up through the villages of Newton, Newtonville and West Newton, making it necessary to move or destroy a large number of buildings to widen the street on either side; while on the south side of the street the lots between the street and the railroad were shallow, which made expensive any widening of the street on this side or the acquiring of land from the rear of these lots for sloping purposes in depressing the tracks.

By combining the two improvements the lots on the south side could be utilized, and an act was obtained from the Legislature in 1895 allowing the city to take land for "widening Washington street and abolishing grade crossings" over and above what was absolutely necessary for the work, and to dispose of any remaining land, after the work was completed, that the city deemed proper.

Under the new act nearly all the land between Washington street and the railroad from Newton to West Newton was seized. This made possible the depressing of the tracks with a broad open cut, and the widening of Washington street to a width of 75 and 85 feet, a much needed improvement. This combined improvement necessitated the destruction or removal to other locations of three brick blocks, twenty-two wooden blocks and seventy-one dwellings. The total expense of acquiring this property was about $573,000.

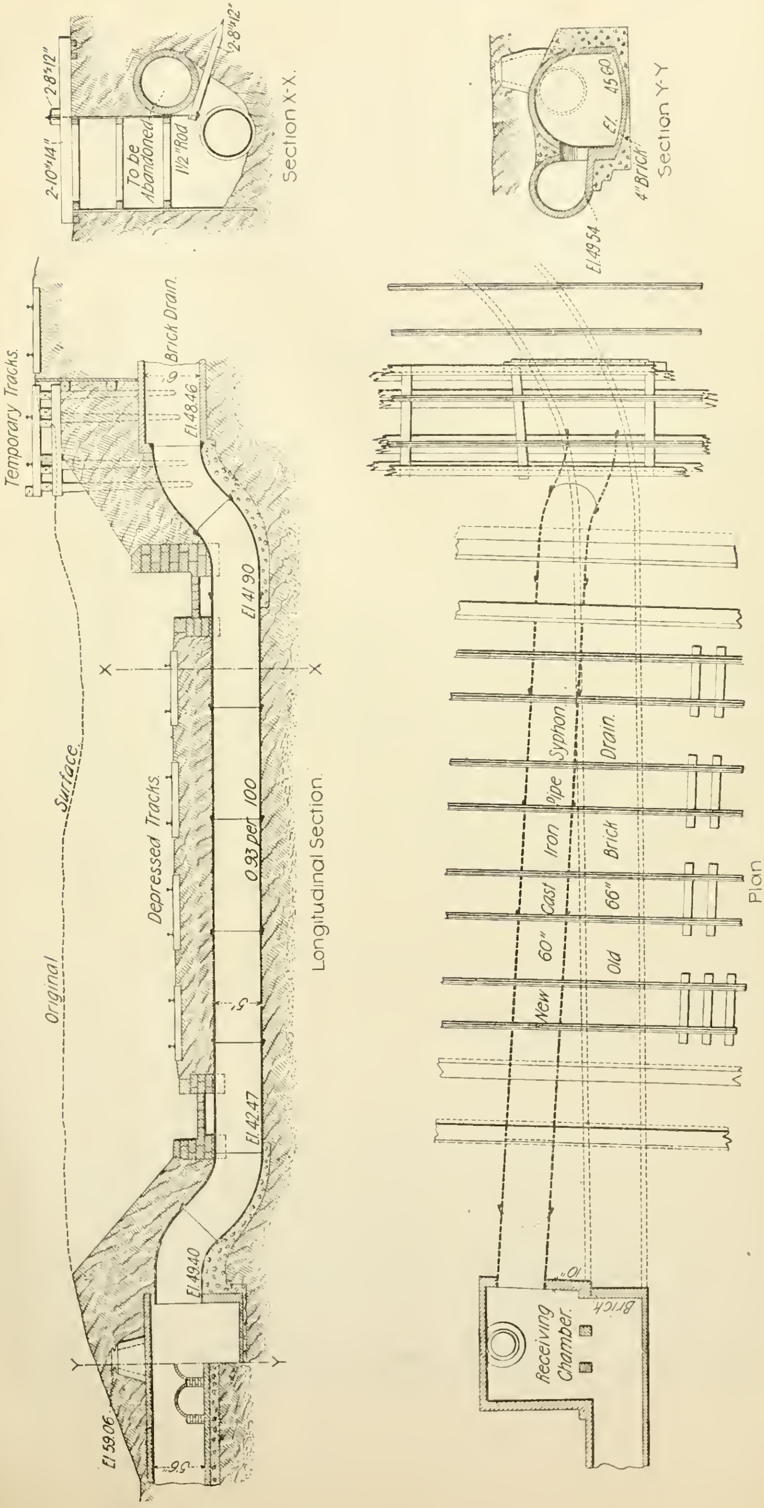
In the final decree of the court the division of cost was made according to the general act on grade crossing; that is, the railroad pays 65 per cent., the city 10 per cent. and the State 25 per cent. of the accounts, as approved by the auditor appointed by the court.

As many changes had to be made in the line and grade of existing brooks, drains and sewers, the decree of the court included the necessary land takings for new locations and widening existing brooks. Another feature of the decree is that portion which refers to rights to slope the filling beyond the limits of the street. The wording is as follows:

"The filling may be sloped beyond the limits of said street so far as may be necessary to hold the embankment, and for this purpose the rights and easement to enter upon the following parcel of land, to construct and maintain the necessary slopes thereon, is hereby taken. Said parcel is bounded and described as follows."

Then follows a description of the parcel of land between the street and the proposed foot of slope, described by offsets and distances from the street line. These were figured for a two to one slope, allowing one foot berm.

Frequent inquiries have been made of late in regard to this. No objections can be recalled as having been brought in the settlements in Newton for grade damages by this matter. But there seems to have been considerable trouble caused by taking rights to slope in other city work, not only in Newton, but, as the writer understands it, also in Boston and other places. The trouble seems to be in getting a wording which will confer the privilege desired by the city of supporting the sides of the street by slopes, without going to the expense of retaining walls, and yet not take



Longitudinal Section and Plan, Worcester Street Siphon.

from the abutting owner any of his rights to use his land as he may desire, provided he does not interfere with the street or endanger its existence. If he desires, he can substitute a retaining wall for the earth slope, using proper precaution of shoring while the work is in progress, and thus be able to build clear up to the street line.

The city does not desire to own any land back of the street line, but only to maintain that line at the proper grade. It would seem as if a proper form might be devised covering this point which would hold in court.

In establishing the new grades for railroad and streets the controlling feature was the drainage. The tracks were put to a grade as low as possible, all available fall in the three brooks crossing the railroad being utilized; and channels for these three streams were constructed to give an hydraulic grade line during flood flow only 5 feet above the grade of bottom, which necessitated widths of 10, 12 and 16 feet.

The grade of the streets at the bridges was determined by the 16 feet clear head-room allowed by the Railroad Commissioners, to which was added $1\frac{1}{2}$ feet for solid bridge floor, making the street grade about $17\frac{1}{2}$ feet above the grade of the rails. The rates of the street grades at the approaches to the bridges were governed largely by the item of damages to the adjacent property and buildings, and varied, with three exceptions, from 2.87 to 5 per cent. The three exceptions were Lewis Terrace, Mt. Vernon street and Felton street, which were carried up from Washington street to the bridge by a rate of 6, 6.50 and 7.50 feet per 100, these steeper rates being warranted by the old grade on the south side of the tracks, where the street ascended the hill at rates exceeding those mentioned.

The grade of Washington street was raised at its intersection with Walnut, Harvard and Church streets, to meet the new grades of these streets. The maximum change of street elevation was $7\frac{1}{2}$ feet at the Washington street crossing (West Newton), the minimum change being at Centre street, Newton, which was raised only one foot. St. James street, which originally crossed the railroad on a bridge with an ascending grade on either side, was lowered 4 feet at the railroad, to give nearly a straight grade from its intersection with Orchard street, on the north side of the railroad, to its intersection with Hunnewell Terrace, on the south side. The street will now be carried over the depressed tracks on a deck bridge, there being ample room between the tracks and the street grade for such a structure.

Bellevue street formerly crossed the tracks on a bridge with a

descending grade. Turning sharply to the east, the street descended at a 6.60 per cent. rate to Washington street. Under the new conditions, with Washington street widened on the south side at this point and the tracks moved north, there was no space for approaches to the bridge from Washington street, so this crossing was abolished, and Bellevue street was carried easterly on a new location, south of the Boston and Albany Railroad, along the top of the railroad slope to connect with Church street near the railroad crossing. This new section of Bellevue street is about 1280 feet long, and was built with the necessary sewers and drains. A new crossing was also made at Lewis Terrace, just west of the old Bellevue street crossing, the expenses of the approaches being entirely born by the city.

By a special act passed in 1896, the city of Newton and the Albany Railroad were authorized to include in any petition for abolishing grade crossings not only all public ways, but also all private ways which might exist across the railroad. Under the provisions of this act several crossings which had never been made public were changed, and in one case, Greenwood avenue, was discontinued and a substitute placed at a different point. Also several new crossings were included in the act, one which replaced a footway under the track at Centre Place, and one at Richardson street, where a crossing had existed before the railroad was widened to four tracks.

It was under the provisions of this act that Austin street, on the south side of the track, was extended westerly from Greenwood avenue to Hillside road, West Newton, as it was impossible to have a raised crossing at Greenwood avenue, owing to the proximity of Washington street to the railroad. A new crossing had to be substituted for Greenwood avenue at Felton street, some 530 feet to the west, near the location of an old right of way which had not been used for many years, but where a gate existed in the railroad fence. This extension of Austin street was found necessary to give access to the new crossing at Felton street to parties who had previously used Greenwood avenue.

The changes in street grades, as well as in the drains and sewers, were made by the city forces, under the supervision of the City Engineer and Superintendent of Streets.

The changes in the sewers and drainage system were of considerable magnitude, necessitating the lowering of 4300 feet of sewer and the construction of two inverted sewer siphons. Of the storm-water drains there were constructed or relaid 4870 feet of brick drain, varying in size from 30 to 51 inches, and one inverted

siphon 5 feet in diameter, besides 3720 feet of pipe drain. The change in grade of the brooks extended over a total distance of 1.2 miles, of which 4830 feet were of the covered or closed section.

Hyde Brook, which crosses the tracks diagonally at Washington street, Newton, was the first to be lowered. This brook has a drainage area of 357 acres, and was constructed for a flood

TABLE SHOWING CHANGES IN DEPRESSION OF BOSTON & ALBANY TRACKS THROUGH NEWTON.

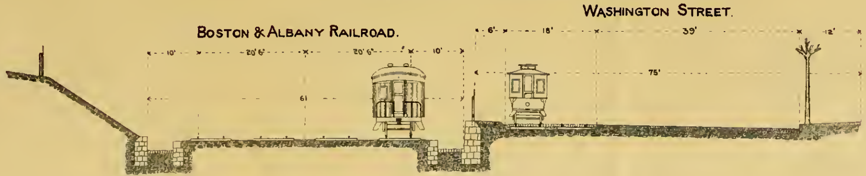
Street Crossing.	Street raised.	Tracks low'r'd.	Bridges.		Bridge Seat.	Height Truss or Girder.	Roadway.	Sidewalks.
			Width.	Length				
Com'w'lth Av.,	18.50	....	80 ft.	72.57	67.79	9′-0″	2–30′.00	7 ft.
Washington St.,	7.80	10.20	85 ft.	109.92	102.97	17′-4″	{ 2–21′.00 21.50	7 ft.
Putnam St,	5.00	10.85	40 ft.	67.33	61.46	8′-6″	25.00	6 ft.
Chestnut St.,	6.10	11.40	49.50	67.33	61.46	8′-6″	30.00	8 ft.
Highland St,	6.00	11.85	42 ft.	67.33	61.27	8′-2″	25.00	6′-10″
Felton St.,	8.15	10 00	40.00	67 33	61 46	8′-6″	25.00	6 ft.
Mt. Vernon St.,	7.34	10.45	40.00	67.33	61.47	8′-6″	25.00	6 ft.
Appleton St.,	5.13	12.60	50.00	74.00	68.45	9′-0″	30.00	8′-4″
Walnut St.,	3.81	14.17	100.00	67.33	61.47	9′-0″	2–34.00	12′
Harvard St,	5.14	12.74	40.00	67.33	61.46	8′-2″	25.00	6 ft.
Lewis Terrace,	6.16	12.20	40.00	71.67	66 00	9′-0″	25.00	6 ft.
Church St.,	4.60	13.00	50.00	72.42	67.02	9′-0″	30.00	8′-4″
Richardson St.,	3.92	13.75	40.00	67.33	61.46	8′-6″	25.00	6 ft.
Centre Place,	2.91	14.86	40 00	67.33	61 46	8′-6″	25.00	6 ft.
Centre St.,	1.44	16.35	71.00	102.42	93.77	20′-3″	2–23′-4″	9 ft.
Washington St.,	1.69	16.45	77.00	89.33	82.55	9′-0″	2–26.00	9 ft.
St. James St.,	*4.50	14.10	30.00	....	....	....	20.00	5 ft.

*Lowered.

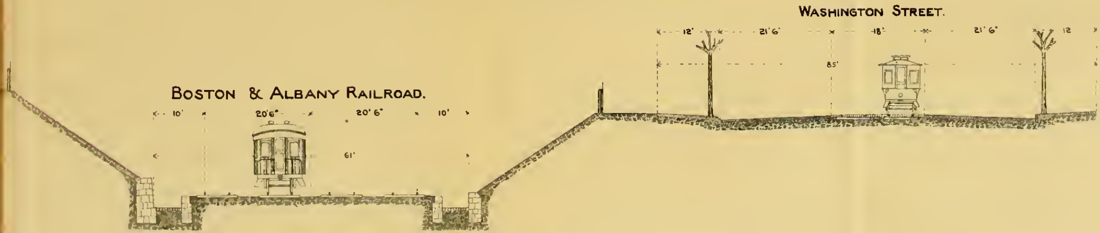
Total length of change in grade of railroad........	19,300	feet, or 3⅔ miles.
Grass slopes on both sides for.....................	12,885	"
Grass slopes one side, wall opposite...............	4,695	"
Walls on both sides................................	1,720	"
	19,300	"
Walls over 6 feet on both sides....................	660	"
" " " on north side only...............	3,160	"
" " " on south side only...............	1,658	"

discharge of 714 cubic feet per second, which, on a 6-10 rate, required an effective area of 50 square feet. In order to pass under the depressed tracks it was necessary to lower the bed of this brook 17 feet; and to clear the bridge abutments a new location was taken, crossing the tracks at right angles west of Washington street bridge, Newton, passing through Washington street and Charlesbank road to connect with the drop manhole in the old brook in private land about 390 feet from the railroad.

Section at Parsons Street.



Section West of Walnut Street.



Cross Sections of
Boston & Albany R.R. and Washington St.

Newton, Mass. Dec 1895

0 5 10 15 20

Scale of Feet

0 1 2 3 4 5 6 7 8

Scale of Metres.

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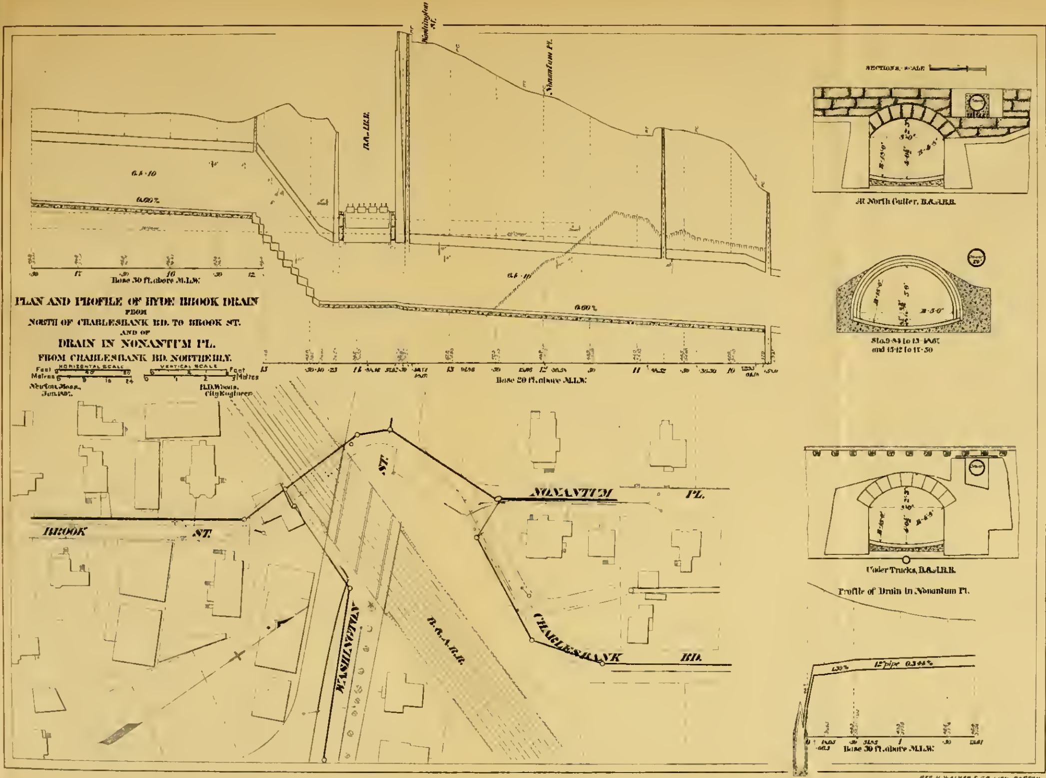

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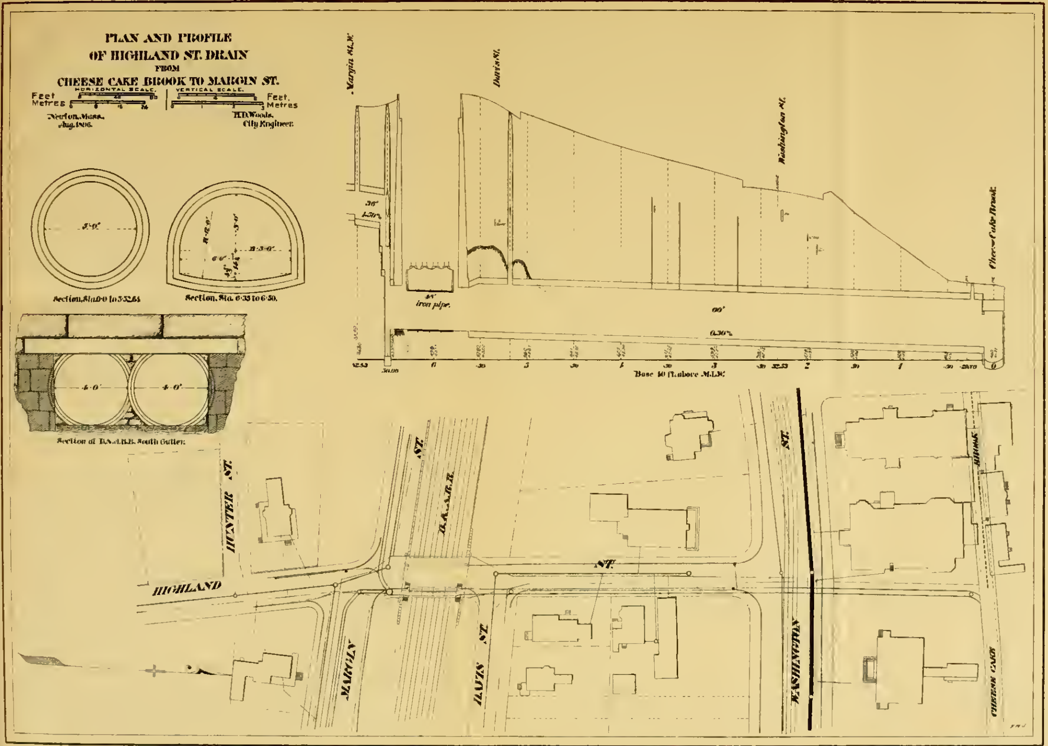

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The section adopted was a semicircular brick arch of 5-foot radius, with a flattened invert, which, with the water flowing 5 feet in depth, gives the necessary area of discharge. The alignment of this brook was necessarily quite indirect, the turns being constructed on curves of 40-foot radius. About 200 feet of 20-inch sewer was also relocated and built on the haunch of the arch in the same trench. The portion of this drain under the tracks was built with a stone arch by the railroad forces. On the south side of the tracks the brook was brought up to the regular grade at Brooks street by a series of granite steps. The cost of constructing this brook, with an average cut of 20½ feet, including the excavation of 1400 cubic yards of rock, was about $35 per running foot.

The second stream to be lowered was Laundry Brook, which crosses the tracks between Newton and Newtonville. This brook is formed by the junction of Hammond and Cold Spring Brooks, and drains a water shed of 2800 acres south of the railroad tracks. The plans for future development of this brook and the city drains tributary thereto requires a capacity for a discharge of 860 cubic feet per second, which, with the available grade of 36-100, calls for an area of discharge of 71 square feet. To obtain this, with the available head-room under the depressed tracks, which was only 5 feet, it was necessary to make a channel 16 feet broad.

The brook, after leaving the railroad, crosses Washington street, flowing for a short distance through developed property, whence it meanders through low lands with low side walls to the Charles River. The depression of the tracks made it necessary to lower the channel at the railroad 5 feet, to gain which the grade was changed from Pearl street to the railroad, a distance of 2500 feet.

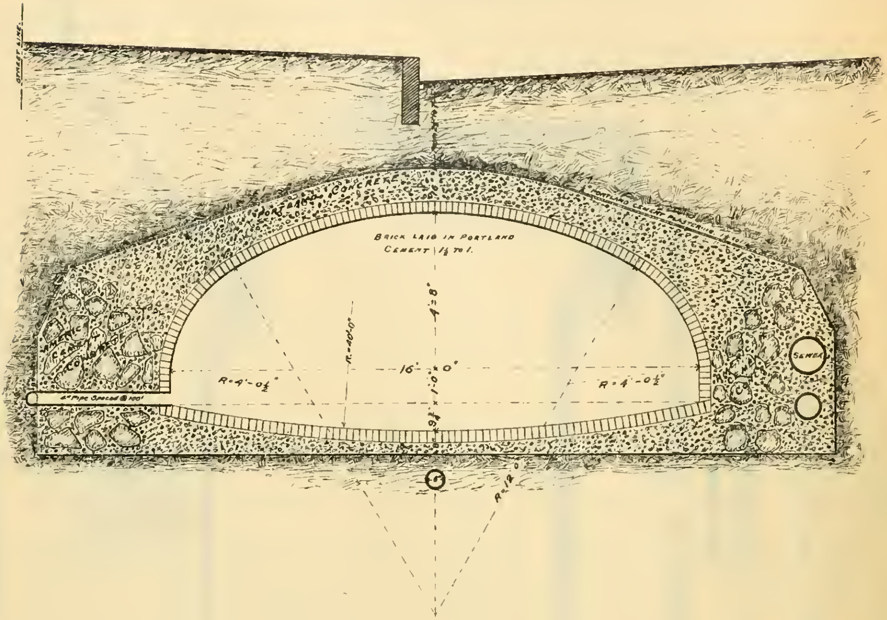
Beginning at Pearl street, the brook was carried on a new location in an open channel with grassed slopes, through the low land, a distance of 1160 feet, or 183 feet shorter than the old winding stream. The channel was constructed with paved bottom and low side walls, from which the banks rise on a three to one slope. Through the higher land an open brook meant side walls of excessive height or a large area for sloping purposes, necessitating heavy damages. To avoid this item of large damages the brook was carried in a closed culvert, similar to that constructed under the streets. This was a concrete arch with side walls one foot high and a flat invert, the whole lined with one course of brick. On account of the wide span and the limited head-room over portions of the arch, it was built as flat as practicable, the basket-handle type being

adopted, with a radius of 12 feet for the middle portion, connected on the sides with curves of 4 feet radius. The brick was laid in Portland cement, mixed one and one-half to one. American cement concrete was used in the invert and on the sides, where it was stepped off to receive the Portland concrete of the arch proper. The concrete in the arch was made from the best English Portland cement, thoroughly tested, and was mixed in the proportion of one, three, four. The thickness of concrete at the crown was 12 inches, making, with the brickwork, a total thickness of 16 inches at the crown of the arch under the street surface. This was reduced to 12 inches in the private land, where the covering was light. A plastering of Portland cement ½ inch thick was carried over the whole, and where the concrete came so near the surface as to be effected by frost the arch was coated with a wash of tar and asphalt, to exclude the moisture.

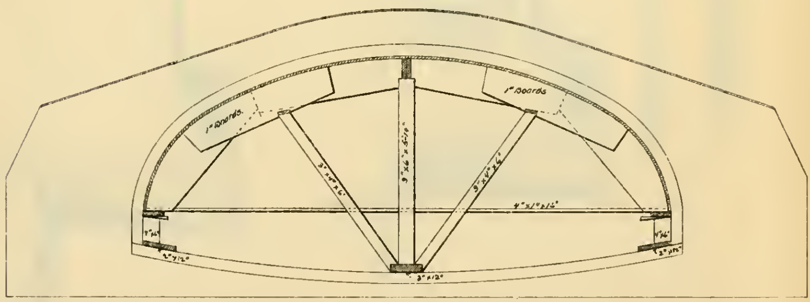
Layers of stone from 4 to 12 inches diameter were laid in the side walls, around which the concrete was rammed. This added to the weight and reduced the amount of concrete. The concrete was rammed in place in 6-inch layers, care being taken to get good bond between the layers and keep the whole as near homogeneous as possible. On the sides where sheathing plank were required the concrete was filled in solid against the planking, which was cut off above the concrete and left in place. The centers for this work were built in 10-foot sections of two pieces each, joined at the crown and braced as shown. To build around the curves special curved centers were made, with a radius of curvature of 40 feet on the center line. There was constructed 1365 feet of this form of brook, about half of which is under the street. The cost, exclusive of the land damages, was $28.75 per foot, the masonry alone costing $18.76. The culvert for this brook underneath the tracks consists of three lines of cast iron pipe 5 feet in diameter, which was laid in 12-foot lengths, supported at each end on masonry piers. The joints were made tight with cement mortar, and the space between the pipes was filled with concrete.

The change of grade of Cheese Cake Brook, at West Newton, was the most expensive of the brook changes for depressing the tracks. This brook has a drainage area of 826 acres south of the Boston and Albany tracks, and, after crossing the tracks, it flows through a closely built section for some distance. One factory and many other buildings have been built close to the side of the brook, in some cases the brook wall forming the foundation for one side of the adjacent building. Under these conditions, any change in the brook meant heavy expenditures for construction as

SECTION UNDER WASHINGTON ST.



DETAILS OF CENTRES.



LAUNDRY BROOK DRAIN.

SCALE OF FEET.

0 1 2 3 4 5 6

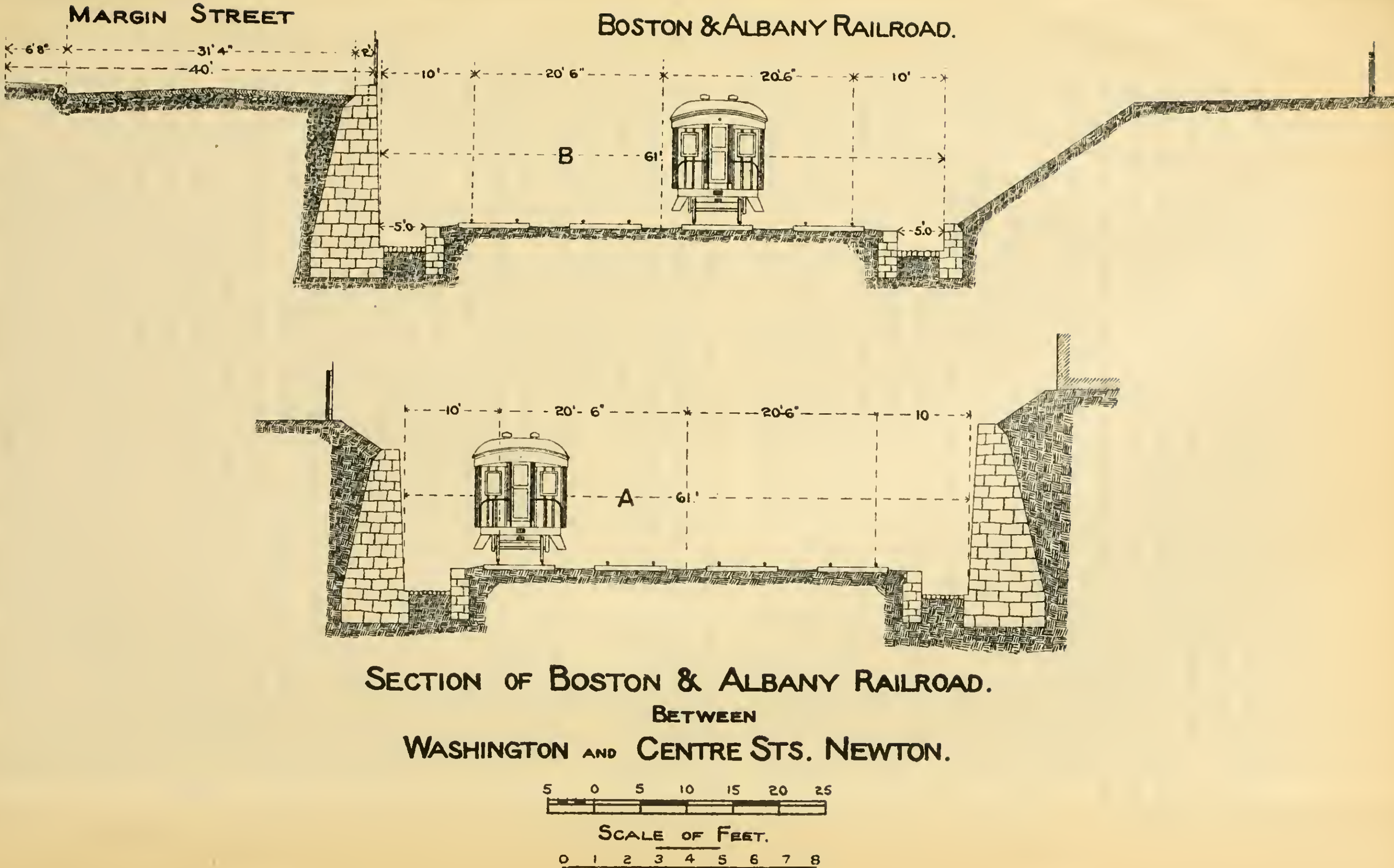
NEWTON, MASS., MAY 1886.

SCALE OF METRES.

0 1 2

H. D. WOODS, CITY ENGINEER.

Geo. H. Walker & Co. Lith. Boston.



SECTION OF BOSTON & ALBANY RAILROAD.
BETWEEN
WASHINGTON AND CENTRE STS. NEWTON.

Geo. H. Walker & Co. Lith. Boston.

well as for damages. The damage question for a long section which was closely built up was settled by an arrangement with the property owners, by which the brook should be covered over. By covering the channel the abutting properties were at once relieved from the nuisance of an open drain into which all manner of filth and refuse had been dumped, despite the police and health officers, and the appearance of this part of the city was greatly improved.

It was necessary to lower this brook 5.8 feet at the railroad, and to accomplish this the whole line of brook from Germain street to the railroad, a distance of 3260 feet, was lowered. The rate of grade for most of the distance was only 16-100 per hundred. This low rate, with the limited head-room at the crossings, required a widening of the channel from 8 to 12 feet. But this widened channel is not equal to the discharge of the water from the branch of this brook which enters north of the railroad, it being proposed to cut a channel northerly to the Charles River for the discharge of this branch brook whenever the capacity of the present channel is exceeded.

The new channel was built with vertical side walls, which extended one foot below grade, and were built to the surface, or $5\frac{1}{2}$ feet high, where the brook is covered, which gives an area of discharge of 60 square feet with $\frac{1}{2}$ foot clear space from top of water to bottom of covering.

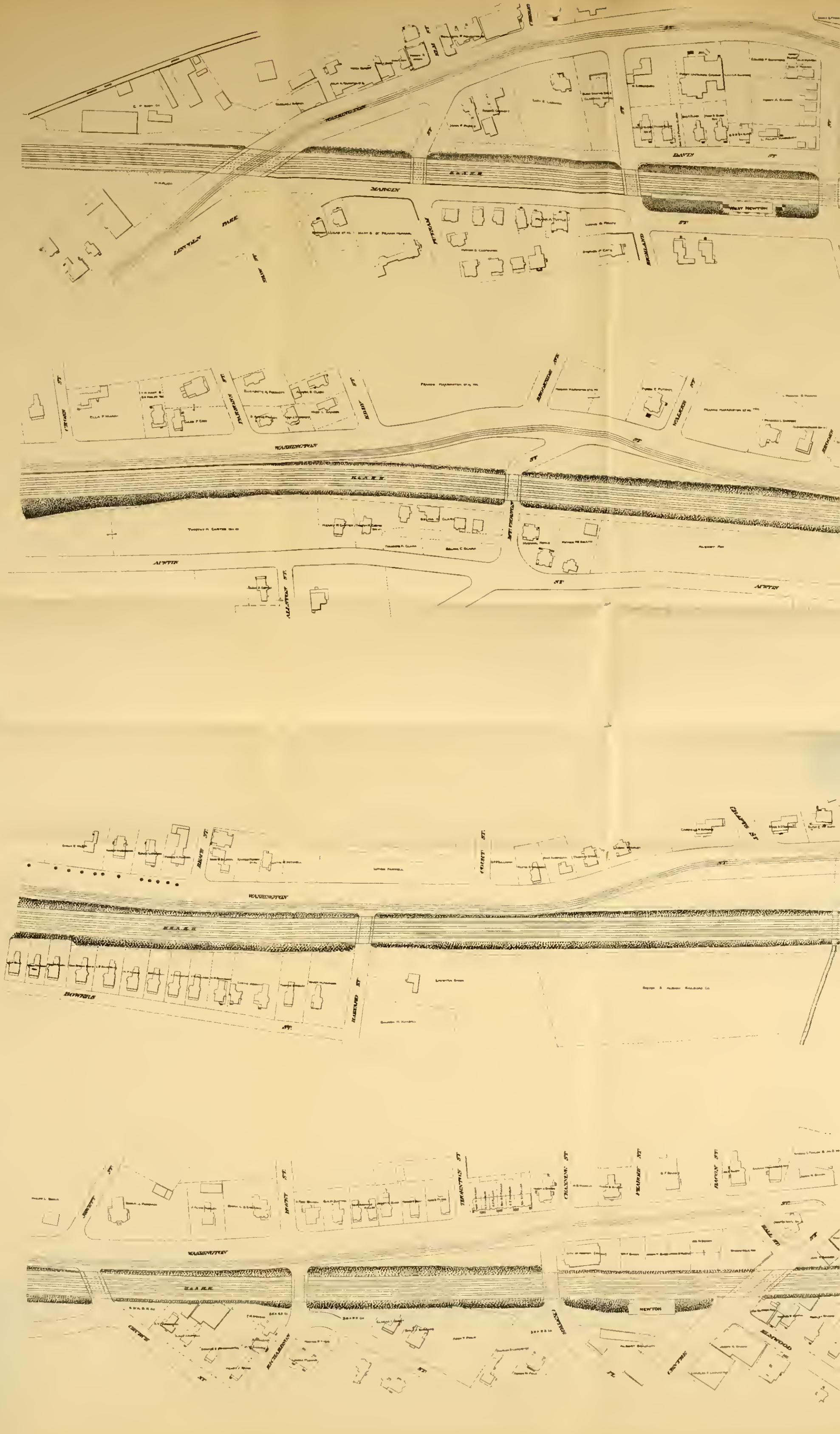
There were six streets crossing this section of the brook. At these crossings steel and masonry bridges were constructed of 10-inch I beams, weighing 30 pounds per foot, spaced 2 feet 11 inches and arched with 4-inch brick arches, covered with Portland concrete to a depth of about 6 inches above the I beams. The surface of the concrete was given a slope of 2 inches from the center of the brook to the sides, and the whole surface, after being plastered with Portland cement plaster, was coated with a mixture of asphalt, pitch and tar, mixed in the proportion of five barrels of coal tar to three barrels of Trinidad asphalt.' In turning the arches special molded brick, made from patterns, were used to fit the flange of the I beam at the springing line. These bricks cost about double the price of the ordinary brick, but saved the extra cost in brick that would have been broken and wasted, and the labor of cutting, besides giving much stronger and neater work. The ends of these culverts, where exposed, were finished by a cut-granite face stone, and a retaining wall to hold the street filling in place. This same method of covering with 8-inch I beams was used in private land. The remaining covering for brook, where there was very light filling and no chance for a load to come on the center, was made of

granite covering stones varying from 10 to 14 inches in thickness.

The brooks being lowered, the six storm-water drains crossing the railroad, with the exception of the Worcester street drain, could be lowered below the tracks and discharge by a straight grade into the brooks. The Worcester street drain could not be so disposed of. It consisted of a $5\frac{1}{2}$-foot circular brick channel, and the grade of the depressed tracks required a lowering of 7 feet. By making a summit in the grade of the railroad gutter, near this point, no outlet was required for the drainage of the railroad; so that it was possible to carry the drain beneath the depressed tracks under pressure, returning to the original drain grade on the north side of the tracks. This was accomplished by using 60-inch cast iron pipe laid in 12-foot lengths, joints calked with lead. The change of direction at each end was made by using two special eighth bends. The pipe weighed from 15,500 to 16,700 pounds each, and were handled with the same derrick used for hoisting the material excavated from the trench. This derrick was well stayed with eight guys, and in handling the pipe triple blocks were exchanged for the single blocks used in excavating.

To avoid breaking into the old drain during construction, which would have meant flooding the work during every storm flow, the line of the siphon was offset 10 feet to the west at the south or upper end, the intervening space being occupied by a chamber constructed to serve as a settling basin. From this chamber the line converged to meet the old drain line on the north side of the track. By this means the bends on the south side and three of the straight pipes could be laid without undermining the brickwork of the old drain. For the remaining distance the drain was undermined, being supported by cross-pieces driven well into the side of the cut, and braced from the bottom on one end and suspended by $1\frac{1}{2}$-inch tie rods at the end projecting into the trench. These tie rods were run through long cross-pieces at the surface, and threaded at the upper end so that a suitable tension could be given to the rod before the earth was excavated from under the drain. These rods were in the line of the sheeting, which was driven so as to fit closely against the side of the old drain to prevent any lateral movement. The cut for this work was largely in loose embankment, and close to the original drain trench, requiring extra care in sheathing and bracing.

The main cross-braces were spaced a little more than 12 feet, the length of the pipes, apart. As a precautionary measure, intermediate braces were loosely driven in place, which could be removed from each section while lowering a pipe. To place the last


DAVIS ST
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WEST NEWTON
LINCOLN PARK
WASHINGTON ST
AUSTIN
AUSTIN ST
MT. VERNON
WASHINGTON
B. & A. R. R.
BOWERS ST
HARVARD ST
COURT ST
CRAFTS ST
BOSTON & ALBANY RAILROAD CO.
WASHINGTON
THORNTON ST
CHANNING ST
PEABODY ST
BACON ST
HALL ST
NEWTON
CENTRE
ELMWOOD
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CHURCH


PLAN OF
WASHINGTON ST. WIDENING
FROM PERKINS ST. TO PARK ST.
NEWTON MASS.
JANUARY 1896
SCALE OF FEET.
0 25 50 100 200 300
SCALE OF METRES.
0 8 16 24 32 40 80
Geo H Walker & Co. Lith Boston
H.D.WOODS
CITY ENGINEER
WASHINGTON
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B. & A. R. R.
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AUSTIN
HILLSIDE
AVE
WALNUT
CENTRAL
AVE
BAILEY
TER
LOWELL
NEWTONVILLE STATION
BOWERS
ADAMS
ST.
CRAFTS ST.
BELLEVUE
LEWIS
CHARLESBANK
ORCHARD
HUNNEWELL
HALL ST.
NEWTON
CENTRE
PARK ST

two special pipe the brick wall was broken out, and the final connection with the drain on the north side was made under the trestle of the temporary railroad tracks on Sunday, while the trains were running on the opposite track. The total cost of this siphon, including the cost of the iron pipe, was $5110. The joints took 120 pounds of lead each, and cost $13 per joint.

The original plans for separating the grades, as submitted to the Grade Crossing Commission, called for no lowering of the West Newton Station. The descenet of 14 feet from the station to the platform was to be made by a flight of some twenty steps at each end of the station. The patrons of the railroad, residents of West Newton, felt that this climb would be somewhat of a hardship, especially to the elderly passengers daily taking the train, and in June, 1897, the City Engineer submitted plans to the railroad for depressing the north portion of Margin street and the station 10 feet. These plans were accepted by the railroad on condition that the city would bear all the expense of changing the street. These conditions were accepted, and accordingly a contract was let for lowering the north portion of the street and building a retaining wall to support the upper Margin street. The width of the original street was 50 feet; this was widened by taking 4 feet from the railroad sidewalk. This gave an upper sidewalk of 6 feet 8 inches and roadway of 25 feet 4 inches, and a lower roadway of 21 feet in clear width, one foot being taken for the fence and batter of retaining wall. The distance from Chestnut street, on the east, to Highland street, on the west, was 500 feet. The grades of both these streets being fixed by the bridges, it was necessary to make the grade of the depressed street at the approaches on either side of the station on a 9-foot per 100, in order to allow a level space for carriage stand. The expense of this change in street was $4368, which was well warranted by the added convenience to the West Newton passengers.

Nearly all the changes incidental to the widening of Washington street and the separation of grades are now completed, and cost the city to date $962,600. Of this amount, $713,742.40 is the cost of widening Washington street, of which but $125,000 was for construction, the rest being for damages. The city has spent on the work connected with grade crossings, for construction, $313,339.42; for damages, $108,014.75; total, $421,354.17. Of this amount, $373,199.74 has been allowed by the auditor as a portion of the grade crossing accounts, and has been repaid by the State, the remainder being wholly chargeable to the city for approaches to new bridges, etc., as also $4378.47 for the depression of Margin

street at the West Newton Station, which was not included in the original plan.

The city's share of the total cost of grade crossing, as ordered by the decree of the court, up to January, 1898, is $196,362.79, or 1-10 of the total expense to date. This amount the city will repay the State in various annual instalments.

The difference in the appearance of the portion of the city through which the tracks have been depressed, and Washington street widened, is much more apparent to casual passengers than to those who have watched the daily changes during the two years of construction, and, although there was considerable criticism when the work was begun, there are now many expressions of approval and the general feeling is one of satisfaction.

II. The Depression of the Railroad Tracks.

By William Parker.

The portion of the Boston and Albany Railroad affected by the work of separation of railroad and street grades, recently completed in the city of Newton, lies between the sixth mile-post, a few hundred feet west of Faneuil Station, and a point about one-half mile east of Auburndale Station, a total distance of 3.65 miles.

Commonwealth avenue crossing, formerly Rowe street, is about 1000 feet west of the point where the depression of the railroad ends. The separation here was accomplished wholly by raising the street.

The distance from Boston to Riverside, on the main line, is 10.7 miles. The total distance from Boston to Boston by the circular route is 22.9 miles.

Most of the trains bound for points on the main line beyond Riverside are express to Riverside.

The main line has four tracks, the two northerly tracks being for express passenger trains and freight trains, and the southerly two for local passenger trains. The Newton Highlands branch and the Circuit are double track, and the Lower Falls branch single track.

Previous to the separation of grades there were nine highway and two private crossings at grade on the main line.

In July, 1895, six months previous to the appointment, by the Superior Court, of the commission to consider the separation of

grades, 153 trains passed over this section of the road daily. Of these, 76 were local passenger trains, 50 express trains and 27 freight trains.

It may be of interest here to note the manner in which these conditions gradually came to exist,—conditions which, in connection with the grade crossing question, called for so much careful and prolonged consideration and discussion, and the changing of which has required the expenditure of large sums of money.

In the 1837 report of the Boston and Worcester Railroad Corporation we find the following: "Passenger trains make two trips each way daily through the year, and during the summer months three trips, stopping at ten places between Boston and Worcester. Freight trains usually make one or more trips each way daily." Quoting further from the report, we have this paragraph: "It is now two years and nine months since the railroad was partially opened for business, and a year and a half since it was opened from Boston to Worcester." By this time, therefore, the railroad was doubtless doing all that it was called upon to do.

Danger there was, no doubt, at grade crossings in those days, when the business of the country made it profitable for a half-dozen trains to cross them daily; but that a railroad company should construct their road, which at that time was almost an experiment, with crossings at grade, instead of resorting to the more costly method of underneath or overhead crossings, can scarcely be thought strange.

In 1842 the second track through Newton was constructed.

From 1883 to 1887 the third and fourth tracks were laid, the portion of the Woonsocket division of the New York and New England Railroad between Brookline and Newton Highlands was purchased and double-tracked and the connecting road between Newton Highlands and Riverside built, giving practically a double-track circuit road from Brookline Junction, independent of main line express tracks.

In 1893 the third and fourth tracks were laid on the main line as far as Lake Crossing, 16 miles from Boston.

It was therefore possible, as far as the operation of the railroad was concerned, to run with safety a large number of trains, many of them at high speed. Meantime, it is needless to say, the traffic on the streets had increased in proportion to that on the railroad.

The question of separation of grades began to be considered seriously about January, 1888. At that time the railroad company made a profile of the road from Faneuil to Auburndale, and surveys of the railroad and adjoining streets as far west as Harvard street.

A profile for the elevation of tracks and depression of streets was drawn, and an estimate made for the construction of about $1\frac{1}{2}$ miles of the work in accordance with it.

In accordance with Chapter 90 of the Acts of 1888, the Governor appointed three civil engineers to report to the general court, "on or before the first day of February, 1889, upon the subject of the gradual abolition of the crossings of the highways by railroads at grade, with such suggestions and recommendations as to the best method of accomplishing such abolition as shall seem to them expedient."

These engineers were appointed July 11, 1888, and their report was dated January 31, 1889.

This commission reported upon all the crossings in the State, and, for the crossings in Newton, recommended that the railroad be depressed through Newton and Newtonville and raised through West Newton. Over the portion which they proposed to depress they did not generally call for as much change of railroad as was finally adopted. The greatest amount was 16 feet. With the exception of Commonwealth avenue, the most that they proposed to raise the railroad at a street crossing was 10 feet, which was at Washington street, West Newton. Their estimate of the cost was $1,300,000.

So far as the writer knows, the next work for the advancement of the grade crossing scheme was that done by the railroad company in the first part of 1892. New railroad and street profiles were drawn and presented at a hearing before the Board of Aldermen in January. Estimates were made of the cost of that portion of the work necessary to eliminate the West Newton crossings. Some of these estimates were based upon a plan for moving the railroad somewhat north of its present location, from Greenwood avenue to Rowe street (now Commonwealth avenue). Work on these plans and estimates continued from time to time through the spring.

Meantime an act had been passed by the Legislature relating to the disposal of private ways across the railroad, as well as highways crossing over the railroad by bridges, in connection with grade crossing work.

Next in order came the appointment of the City Commission. By an order of the City Council of the city of Newton, approved November 22, 1892, a commission was appointed, consisting of the City Engineer, Albert F. Noyes, and two other engineers, Charles A. Allen and George S. Rice, who were, in the language of the order, "to examine the several proposed plans for separating the

grade crossings of the Boston and Albany Railroad within the limits of the city of Newton and report thereon." The order specified three different methods to be considered.

The commission made their report May 1, 1893.

As specified by the order, the first method to be considered was the removal of the tracks to some other locality. The commission selected a route which left the main line about 800 feet east of St. James street, and passed to the north of the present location, joining it again at Auburn street, Auburndale. At Newton, Newtonville and West Newton stations it was respectively 850, 1900 and 800 feet north of the present location. The greatest departure, however, was opposite Bellevue street, where it was about 2100 feet. Estimates were made for both depressed and elevated tracks on this line. With the depressed tracks a tunnel about 600 feet long was required. With the elevated tracks grades of 39 and 51 feet per mile were required.

The second method considered was to raise the tracks and depress the streets in their present locations. The commission recommended the raising of the railroad at important street crossings from about 12 feet to about 16½ feet, the streets being lowered from 1 foot to 5½ feet. The railroad was to be carried over the streets by arches of steel or masonry. The profile of the railroad was somewhat irregular, and called for some steep grades.

By the third method the railroad was depressed and the streets elevated in their present location. The railroad was placed as low as possible consistent with good drainage. The depression at the street crossings amounted to from 9 to 16 feet. Sixteen feet clear head-room between top of rail and under side of bridge was reckoned upon. The streets were to be raised from 2.3 feet to 9.6 feet, except at Rowe street, where, as there was to be no depression of tracks, the street was to be raised 18.5 feet. Both schemes for changes on the present line of railroad provided for four highway bridges where there were formerly no crossings, and one highway bridge at Centre Place, where there was formerly a foot subway, and a foot bridge at Greenwood avenue, where there was formerly a private way at grade.

A summary of the City Commission estimate is as follows:

Proposed northern location, with depressed tracks and slopes, $2,455,700. Raised tracks, with slopes, $2,647,000; with walls, $3,741,000. Present location, depressed tracks, with slopes, $2,090,300; with walls, $2,370,600. Raised tracks, with slopes, $1,965,300; with walls, $2,251,500.

In conclusion, they strongly recommended that the tracks should be elevated.

The report was very carefully prepared, and was illustrated by maps and numerous profiles of both railroad and streets. Much that pertained to such matters as the widening of Washington street I have not mentioned, merely touching upon that which most directly affects the railroad work and helps to complete the list of the many efforts to solve the grade crossing question.

There was considerable opposition by the Newton people to the scheme of elevating the tracks, recommended by the City Commission, and this was manifested at a public hearing in June, 1894.

Nothing more of consequence was done until January, 1895. At this time the city government proposed taking all the land between Washington street and the railroad in connection with the widening of Washington street, over the greater part of the distance covered by proposed changes of the railroad, and by so doing provide room for temporary tracks over which trains could be run while the work of depression was going on.

The railroad company approved of this method, and the city and railroad company drafted an act which was passed by the Legislature in March, 1895, which gave the special powers required to carry out the work as suggested.

From this time on the work of completing the final plans was continued by the railroad company's engineers working in conjunction with those of the city.

On June 26, 1895, a public hearing was held at City Hall to consider the general plans proposed by the engineers. They proved to be satisfactory to both parties, except in minor details, and written agreements between the city and the railroad company, concerning methods to be pursued by both, were drawn up and signed.

The plans being fully agreed upon by the railroad company and city, the petition to the Superior Court for the appointment of a commission was submitted in December, 1895.

The commission was appointed January 2, 1896, and consisted of George W. Wiggin, Joseph S. Ludlam and Homer Rogers.

After a hearing and view of the crossings and several adjournments of the hearing, the commission filed their decision and prescribed the manner and limits within which the alterations they decided upon should be made. Their decision was filed February 29, 1896. The decree of the court confirming the decision was dated March 3, 1896.

The decision of the commission as printed covered fifty-six letter-size pages.

After a preamble, which contained references to some general matters relating to their appointment and to the taking of land for temporary tracks, they proceeded to describe in detail the manner in which the alterations were to be made.

The new base line of location of the railroad was first described by starting at a point a certain distance from the sixth mile-post and giving the lengths of tangents and curves on the new line, and the radii of the curves, calling for stone monuments at all points of change and giving the stations of each. The new north side line of location was next described by starting at a certain distance northerly from the point of beginning of the previously described base line, thence running westerly by a line located by reference to the base line, or to establish property lines intersecting the new side line, or both.

The southerly side line was next described in the same manner as the north line.

Next came the description of the different parcels of land taken, which were outside the present location of the railroad. There were twenty parcels in all, each parcel being described much the same as in the case of descriptions contained in deeds.

The grade of the railroad was next established by giving the elevations at points of change, designated by their stations, and the gradients.

The matter of dealing with streets will be described by the paper to be presented to you by the city's engineer, as well as a description of the changes necessary in the water courses and sewers.

The position of culverts of masonry or iron pipes was given.

Retaining walls of masonry laid in cement were to be built, where shown on plan, and ditch walls were called for.

Land was then taken for railroad slopes, twelve different parcels being described.

It was then stated that the railroad company should do all the work within the lines of the railroad location, and that the city of Newton should do all other work ordered.

The commission decided that the commonwealth should pay 25 per cent. of the total cost of the work and the city of Newton 10 per cent., leaving 65 per cent. to be paid by the railroad company.

A plan, in the form of a tracing, was filed as a part of their decision. It was drawn to a scale of 40 feet to an inch, and showed all existing tracks and all structures and property lines adjoining the railroad property or Washington street. A profile of the railroad was shown on the same sheet also, as well as profiles of all

streets affected by the decision of the commission. The lines showing the changes ordered were red or yellow, and of different conventional kinds.

Showing so much on one sheet at this scale made the plan rather large, 3 feet wide and 45 feet long, but it was, on the whole, very convenient and satisfactory. Three cloth blue prints of it were given to the Clerk of Courts and one to the city of Newton. The railroad company also had one for the Boston office use and one for the roadmaster's office on the work.

The new base line was moved north over a large portion of the work.

From near St. James street to Church street the movement north was from 13 to 9 feet. This was to avoid taking land on the south side. From Mt. Ida west the alignment was changed so as to avoid a reverse curve. At Newtonville station the movement of the base line north amounted to 23 feet. This movement was made practicable by the large amount of space between Washington street and the old railroad location, which was to be taken by the city in connection with the Washington street widening. It made it unnecessary to take valuable land on the south side, and also gave the required room for station facilities. From Newtonville west the new base line is about 19 feet north of the old, as far as the Mt. Vernon street ledge. At this place, on that account, it was not necessary to disturb the old rock slope on the south side, and consequently no land was taken. The new base line gradually approached the old from this point to a little east of Chestnut street, where the two lines come together. At Greenwood avenue the two lines were still far enough apart so that the old retaining wall, holding a high bank on the south side, was not disturbed.

The amount of the depression of the railroad required at some of the important street crossings was about as follows: Washington street, Newton, 16.4 feet; Centre street, 16.4 feet; Church street, 12.9 feet; Walnut street, Newtonville, 14 feet; Chestnut street, West Newton, 11.4 feet; Washington street, West Newton, 10.4 feet.

The actual depth of excavation was about 2½ feet greater than these figures, as sub-grade was 3 feet below top of rail.

A minimum slope of 2-10 per cent. was adopted for ditch grades, and 2 feet 6 inches for minimum depth from top of rail to bottom of ditch. The grade of the tracks is level in some cases, so, for this and other reasons, the depth of ditch below the rail is not uniform. The greatest depth of ditch is 3 feet 10 inches below top of rail. Except where there is ledge, the ditches are paved.

As soon as possible after the decree of the court specifications

for ledge work and plans and specifications for masonry were sent out, and bids received.

Only representative plans of abutment and wall masonry were prepared to send out with the specifications.

The contracts for all work were awarded in April, 1896.

The first work which it was necessary for the railroad company to do was that of preparing a roadway for two temporary tracks about $3\frac{1}{2}$ miles long. Work was commenced early in the spring of 1896. This required the construction of 2500 feet of single and 1040 feet of double-track trestle. One of the single-track trestles extended from just east of Washington street, Newton, to Centre Place, and was built on account of the fact that there were valuable buildings here which it was not thought best to disturb. The next trestle was at Brackett's coal yard. Part of this was double track. The third trestle was that at the city hook and ladder house, near Mt. Vernon street, and was built partly to avoid the entire destruction of this building. These three trestles were all pile structures. The fourth and last trestle was at Eddy's coal yard, and was double track on timber bents, the sills resting directly on the earth. No very extensive grading had to be done, but there were some sharp curves and steep grades. A large number of buildings had to be moved or torn down before the grading could be finished.

On June 28, 1896, all regular business was turned onto the two southerly main tracks, and the work of removing the rails and ties of the two northerly tracks to their position on the temporary roadway was commenced.

July 13, 1896, all the regular business of the road was transferred to the temporary tracks, leaving the old roadway practically free for construction purposes.

In the sections, Figs. 1, 2 and 3, the heavy lines represent the original surface, the hatched lines the finished work and the ordinary lines different stages of the work during construction or details of finished work.

The first cross-section, Fig. 1, shows the work near the St. James street bridge.

The stripping on the right-hand or north side was done by the railroad company's laborers. The other stripping was done by contract in connection with the ledge work. The next operation was that of excavating the rock enough to give room for temporary tracks. The next or third stage was that of excavating on the site of the old third and fourth tracks, the two northerly tracks being reserved for construction purposes. The fourth stage completed the excavation under the old four-track roadway. Work on the

fifth and last stage, of course, could not be commenced till traffic was transferred from the temporary tracks to two of the new and permanent tracks below. This was accomplished July 11, 1897, *almost exactly one year from the time the old roadway was abandoned.* The retaining walls and St. James street abutment, on the south side, were built while work on the fourth stage was going on. The north abutment of St. James street, and the retaining walls just west of it, were built last of all, with the exception of ballast walls.

The next section, Fig. 2, shows the work between Washington street and Centre street.

On the right-hand side there were several buildings which were cut off directly on the location line, which was only a few inches from the back line of the foundation. Much careful sheathing and bracing had to be done here, and special methods for supporting and underpinning the buildings were adopted.

The retaining walls here, as in most cases, were rubble, of large, well-shaped stone, with coping stone of nearly a uniform thickness, the minimum thickness of coping on most walls being 16 inches.

Fig. 4 shows a portion of the work on the north side.

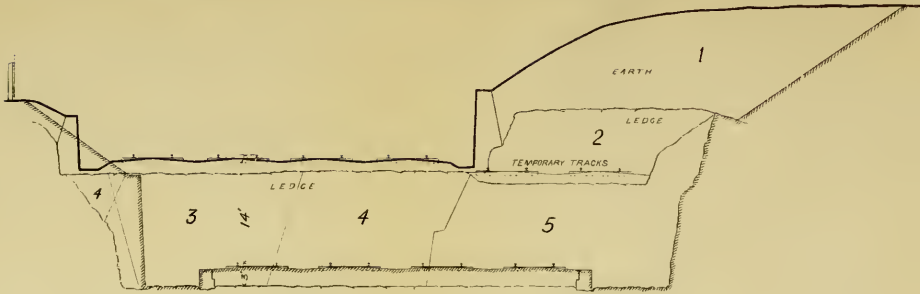
Fig. 5 was taken, when all work was completed, looking west from a point under Centre street bridge. The new station on the left has its floor about 6 feet above the platform. The baggage-room is in a separate building, and has a baggage chute of granolithic from its floor level to the platform. Centre Place bridge is the one next the station. Richardson street, Church street and Lewis Terrace can be seen in the distance.

Fig. 6 shows the finished work from Hunt's carpenter shop, on Washington street, West Newton, to the West Newton Station. On the south side retaining walls and abutments are continuous for a distance of 1300 feet, and contain 5300 cubic yards of masonry.

The third cross-section, Fig. 3, shows the operations of the steam shovel where the proximity of street crossings, etc., did not prevent carrying out the order shown. Old track No. 3 was first used as a loading track, and then was moved down successfully into position as loading track for cuts 2, 3, 4 and 5. Old track No. 4 was lowered for use as loading track for the sixth cut.

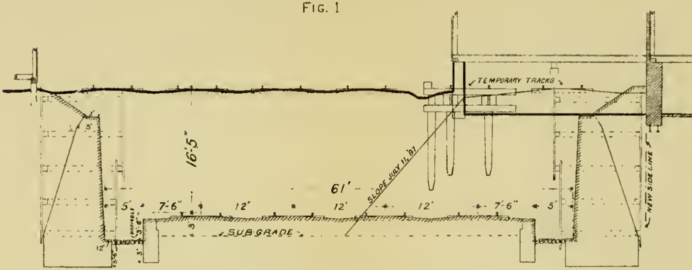
Fig. 7 is a view of the steam shovel work at the trestle at Brackett's coal yard. It was taken looking east from a point a little east of the location of the work illustrated by the diagram, Fig. 3.

The construction track is the loading track marked 3 in the diagram. At this time it is being used by a shovel just leaving



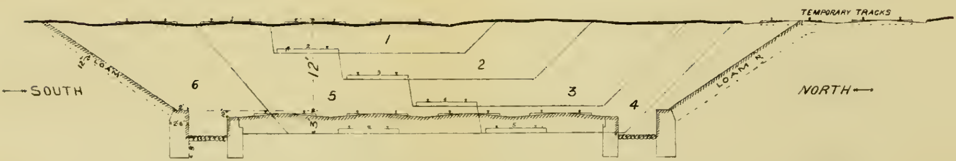
ST JAMES STREET LEDGE

FIG. 1



WASHINGTON ST. TO CENTRE ST.

FIG 2



STEAM SHOVEL WORK

NEAR HARVARD ST.

FIG. 3

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Fig. 4. Steam Shovel East of Centre Street, Oct. 28, 1897.

Fig. 5. Finished Work at Newton Station.

Mt. Ida. The pile of stone on the south side is that which came from the old Bellevue street bridge abutments, and was used for the south abutment of the new Lewis Terrace bridge. The stone lies within the limits of the new street.

Fig. 4 is a view of the steam shovel on the last cut of all the steam shovel work. It is a little east of Centre street. There is another shovel at Centre Place working towards it. The train for this second shovel can be seen about opposite the passenger station. As forty or more regular trains per day passed over the same track that the gravel trains were using, it made steam shovel work rather slow.

One steam shovel began in March, 1896. Other shovels started as there was a chance for them, until four were at work. So much depended on rapid work by them that they were run day and night during September, October and November, 1896. Some night work was also done by one of the shovels in April and May, 1897.

During the busiest part of the season of 1896 fourteen locomotives were in the service daily.

Exclusive of night gangs, the greatest number of men employed at any one time by the railroad company was about 325. The greatest number of men employed upon railroad work at any one time, that is, employes of the railroad company and of contractors working under it, was about 700. The total number of cubic yards of earth excavated was, in round numbers, 706,000. Some of this was used for street filling in Boston under contract with the city, and for filling Commonwealth avenue bridge approaches. The remainder was taken to the dumps at Riverside and Faneuil.

The total amount of rock excavation was about 51,000 cubic yards. About 75,000 yards of ballast was required. Some of this was found on the work, but most of it had to be brought from Wellesley.

There was about 46,000 cubic yards of wall masonry, and the seventeen bridges required about 20,000 cubic yards of abutment masonry.

An arch culvert was required for Hyde Brook, Newton. The old arch stones of Laundry Brook culvert were made to serve for this.

There were several iron pipe culverts, two of them being made up of three lines of 60-inch cast iron pipe. The culverts under the railroad tracks required in all about 700 cubic yards of masonry. So the total for abutments, walls, and culverts was, in round numbers, 66,700 cubic yards.

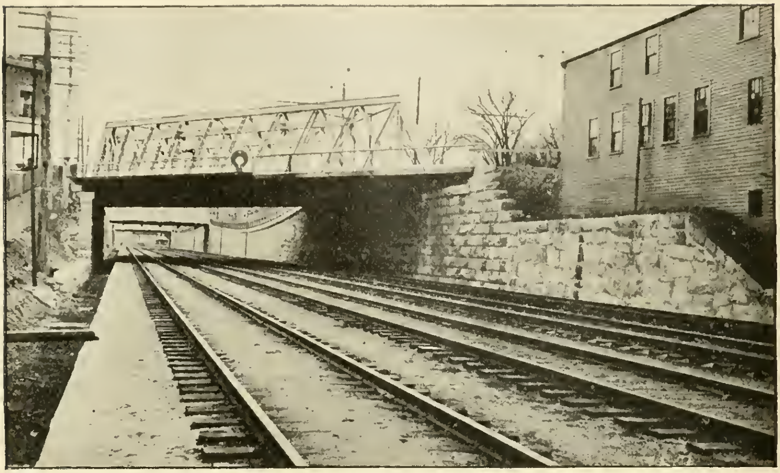


Fig. 6. Finished Work from Washington Street, West Newton, to West Newton Station.

Fig. 7. Steam Shovel Work at Brackett's Trestle.

At Newton a new station of granite, with brownstone trimmings, was built, with the main floor 6 feet above the level of the rail. It is approached by driveways and walks from both Centre street and Centre Place.

At Newtonville the old station was allowed to remain in its original position, steps being built down to the new track level. Walks also connect the platform at the track level with Walnut and Bowers streets.

The old West Newton Station was lowered to within about 5 feet of the new track grade, and the north half of the street in the rear of the station depressed by the city to correspond.

The amount charged to the account of separation of grades by the railroad company for expenditures made by it was, in round numbers, $1,790,000, and by the city $460,000, making a total of $2,250,000 to be apportioned between the railroad company, State and city, in the proportion of 65, 25 and 10, respectively, as decided by the commissioners.

III. Bridges Over the Railroad Tracks.

By W. G. S. Chamberlain.

The separation of grades in the city of Newton made necessary the building of seventeen bridges, all over the tracks of the railroad company, and all within a distance of between three and four miles. Fourteen bridges are plate girder and three are truss spans.

The clear head-room under all the bridges, excepting one, is 16 feet. Under that one it is 18 feet.

The reason for this increased head-room was that the street originally crossed the railroad on a bridge. The grade of the railroad having been lowered, the distance from street grade to that of the railroad was increased so much that it was possible to have a clear head-room of 18 feet and put in a deck bridge. To a person on the street, this bridge will not be particularly noticeable. All that will be seen will be the asphalt surface and the iron fences outside of the sidewalks.

Perhaps the most interesting feature of these bridges is the floor, especially the roadway floor. The foundation for the whole is the same as for any plate girder or truss bridge; that is, floor

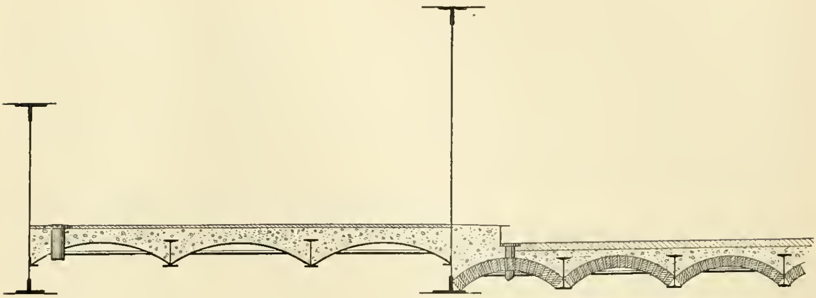


Fig. 1

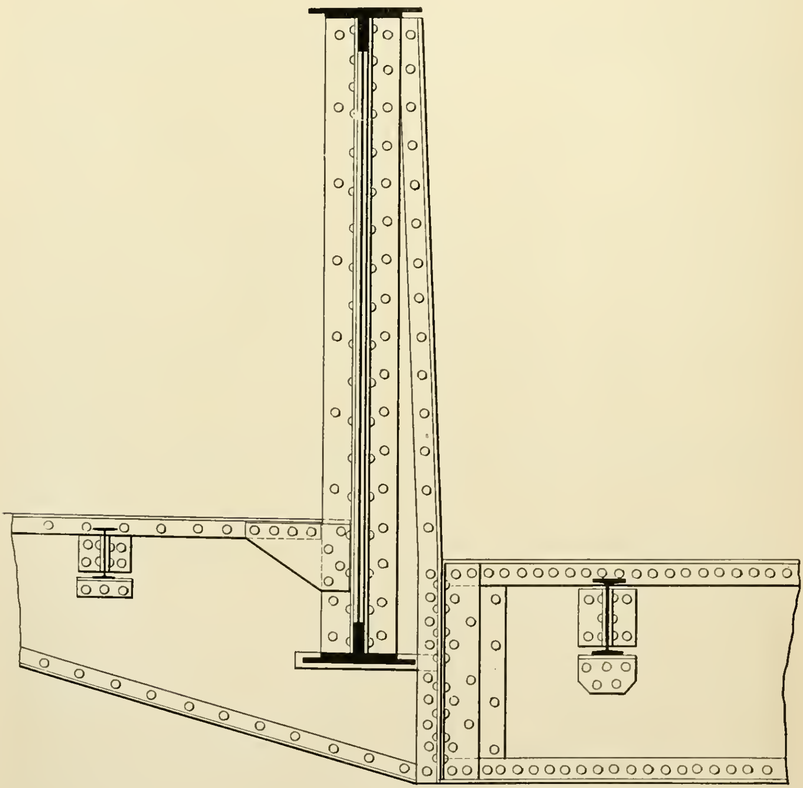


Fig. 2

beams and stringers. The spaces between stringers and girders are filled in with brick arches and concrete, up to within three inches of the finished grade. The remaining space of three inches is filled with one inch of binder and two of asphalt. The surface has a crosswise crown of two or three inches, according to the width of the roadway. Drainage is provided through cast iron scuppers placed each side of the roadway, near the curb channels. The upper end of the scuppers is even with the surface of the roadway, and the lower end is below the lower side of the brick arch. To prevent the smoke from coming up through the scupper, the bottom is curved around, making the outlet on the side. Thus far this arrrangement has seemed to be satisfactory.

The arches have a 4-inch ring, an average span of about 3 feet 4 inches and a rise of 6 inches. The bricks are hard burnt, well shaped and laid in Portland cement mortar. The concrete was composed of one part of cement, two of sand and five of gravel.

The concrete was not placed until the mortar in the arches had set. The centers were not removed until after the concrete had been placed.

In the sidewalks curved plates were used in place of brick arches. Concrete was put in to within one inch of the surface, then the finish was asphalt.

On all bridges where there was no girder outside of the sidewalk the surface was inclined, so that the outer edge of the sidewalk was one inch and a half lower than the inside.

Where there was a girder on the outside, drainage had to be provided through scuppers placed near the outer girder.

When an engine passes under a bridge the exhaust throws clouds of smoke up against the under side of the floor, where it spreads itself out, covering nearly all the under side of the bridge. Near the sides of the bridge the smoke quickly floats out, but back further, in and around the central portion, the smoke will whirl and eddy around, and is much longer in disappearing. The moisture has an opportunity to gather on the surfaces and, holding more or less acid, affects the metal. This was one consideration in favor of the use of brick arches, instead of curved plates, under the roadway. Another was maintenance. Under the conditions already mentioned, it would be necessary, in order to protect the plates, to paint them at frequent intervals. This would be a long and expensive job, as the head-room would not allow the men to work while trains were passing. A third consideration in favor of the brick arch is the strength it gives to the floor between the stringers, thus allowing them to be spaced further apart.

With so little depth to the concrete, it would not seem as if much could be depended upon that for strength.

Fig. 1 shows a section of the sidewalk and part of the roadway. From the surface of the roadway to the lower side of the girder is only about 18 inches. This distance is too small to make proper connection between floor beam and girder; the floor beam also requiring more depth for shear and stiffness. Fig. 2 shows how this difficulty was overcome. The floor beam bracket, made up of a plate and angles, is connected to the girder for its full depth. It is wide enough to allow the angles on the inside to extend vertically down below the bottom of the girder. To these extended angles the floor beam is connected. This arrangement gives the necessary depth for the floor beam. The floor beam is so located in the bridge that it will be midway between tracks and parallel to them. In a skew bridge this makes everything skew, but it cannot be helped. Where the sidewalk is carried on brackets they are connected to the outside of the girder opposite to the floor beam in the same line with it, and then the web and bottom angles are carried down under the girder and connected to the same angles that the floor beam is. This practically makes one floor beam from out to out of sidewalks.

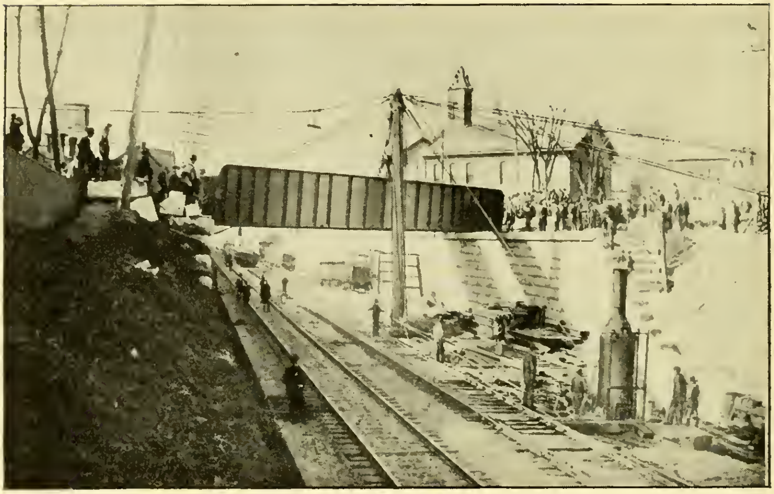
A conspicuous feature of the girder bridges is the great depth of the girders compared with their length. The fact that the distance between the surface of the street and the clear head-room was such that it was necessary to reduce the total thickness of flange plates as much as possible. Hence the depth. The completed bridge does not show this as much as when the girder is seen alone.

The total weight of steel in the bridges is 4,308,238 pounds, giving an average of 253,426 pounds to a bridge. Washington street bridge, West Newton, has the largest amount, there being 583,103 pounds.

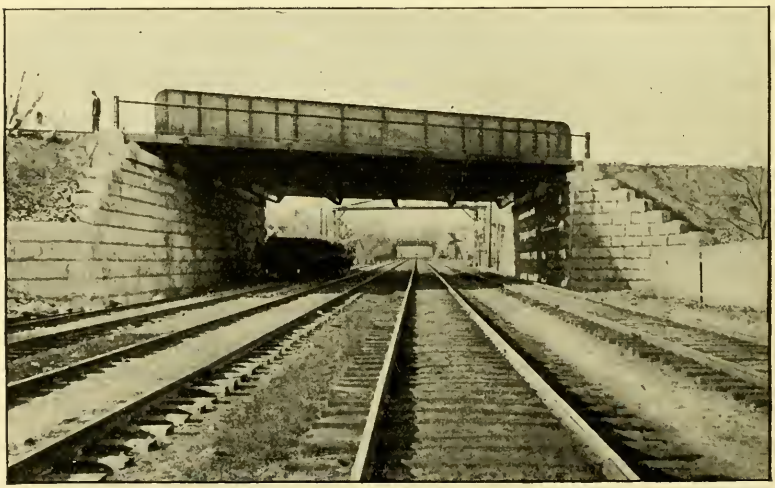
The dead load of the roadway, stringers, arches, concrete and asphalt was taken at about 140 pounds per square foot; that of the sidewalk at a little more than 100 pounds per square foot. The live load for sidewalks was taken at 80 pounds per square foot. The roadway floor was calculated for a 20-ton road roller anywhere upon it.

The material used in the construction of the bridges is open-hearth steel, of either the acid or basic process. It was required that the acid process steel should contain no more than 8-100 per cent. of phosphorus, and the basic no more than 6-100 per cent.

No steel was used which showed less than 54,000 pounds per



Washington Street Bridge, Newton, Raising Middle Girder.



Commonwealth Avenue Bridge, Auburndale.

square inch ultimate tensile strength, or greater than 62,000 pounds per square inch. The elastic limit was placed at not less than one-half the ultimate tensile strength. The elongation required was to be not less than 26 per cent. in a length of 8 inches; the reduction of area at fracture not less than 50 per cent.

As a matter of fact, the material more than filled the requirements. The tensile strength averaged about 60,000 pounds, and the elongation and reduction of area in almost all cases was considerably more than required, while the elastic limit averaged about 36,000 pounds.

The material was all inspected at the mills, and specimens subjected to physical and chemical tests.

All shop work was under constant inspection. This part of the work was performed in a very satisfactory manner by R. W. Hildreth & Co., of New York.

Reports were furnished each week, giving a detailed statement of the results of all tests and inspections at mills and shop.

From these reports it was known how the work was progressing, and about what time the bridge would be ready for shipment.

The bridges were built and erected by the Pencoyd Iron Works, of Philadelphia.

All girder work was shipped complete, no field riveting being required.

While the bridges are not ornamental, they yet have a firm and substantial appearance, and are ample for all that may be required of them.

All the plate girders were raised into position by means of a hoisting engine and gin pole. The foot of the pole rested on rollers, so that it could be shifted without trouble. The guys ran through blocks, with the lead lines belayed to the post, so that the pole could be plumbed or canted without sending men away from the work.

The view showing the raising of the middle girder of Washington street bridge gives an excellent idea of the general arrangements and how the work was done. The girder being raised weighed 31 tons, and just about equaled the hoisting power of the engine. The tackle for hoisting this girder included eight three-sheave blocks, with two lead lines to the engine.

POWER CONSUMPTION ON ELECTRIC RAILROADS.

By S. T. Dodd, Member of the Civil Engineers' Club of Cleveland.

[Read before the Club, January 25, 1898.*]

About ten years ago I saw for the first time an electric street car propelled by the power of *forty horses.* To my mind, acquainted only with ordinary two-horse traction, a double 20 horsepower equipment seemed out of all proportion to the speed and size of the car.

Our ideas on such subjects have changed since those days, and to-day no one would thinkof using less than a double 25 horse-power equipment for street railway work; while double and quadruple 25, 50 and even 75 horse-power equipments are so familiar that they pass through our streets without comment.

I suppose no one would expect to operate a twenty-ton car at a speed of thirty miles per hour with the current it takes to run an arc lamp, yet such a mistake would be no more glaring than some that have been made in the development of electric traction. What I now propose is to make an analysis of the losses occurring in electric railway operation and to show that the power of our equipments is no greater than might be expected from the ordinary laws of mechanics, from the weights we are propelling and the speeds, acceleration and grades which we encounter.

The power necessary for propelling a car or train is equal to the product of two quantities—(1st) the speed, which is a definite, measurable and easily recognized quantity; and (2d) the force, the effort exerted by the motive mechanism, or its equivalent, the train resistance. This latter, being more obscure and less easily measured, deserves a careful study.

In analyzing train resistance, four principal divisions must be noted:

(1) Grade resistance, or the effort necessary to lift a train up a certain slope. In electric railroad work this becomes a more important factor than in steam railroad work, on account of the steeper grades encountered.

(2) Curve resistance, or the effort necessary to propel the cars around curves upon the track. This enters as so small a factor that I shall note it here only for the purpose of completeness, and shall not refer to it again.

(3) Acceleration resistance, or the effort necessary to impart to

*Manuscript received August 20, 1898.—Secretary, Ass'n of Eng. Socs.

a car of given weight a certain velocity in a certain time. On account of the character of the traffic, this becomes a more important factor in electric railroad work than it is in steam railroad work.

(4) Frictional resistance, or the effort necessary to propel a train at a constant velocity over a level track. This division, being the most obscure, shall receive our attention first.

FRICTIONAL RESISTANCE.

The nature of the resistance encountered by moving trains has been discussed by steam railroad engineers for many years. In electric railroad work we have an advantage over steam railroad engineers in the measurement of this quantity. In steam railroad work readings from a dynamometer interposed between the engine and train give only the resistance of the train itself, leaving out of account the resistances experienced by the engine, which in many cases amount to a very considerable proportion of the whole. While the reading of steam engine indicators is a sufficiently laborious and delicate operation on stationary engines, it is much more so when the position of the observer is on the outside of a locomotive running at 25 to 60 miles an hour; and, even with this indicator reading, unless the efficiency of the engine is very accurately known, as it seldom is, we are unable to separate the train resistance from the internal losses in the engine. On the other hand, the determination of train resistance in electric railway work is a very simple matter.

Fig. 1 represents the curves of torque and speed of a street railway motor. These curves can generally be obtained from the manufacturer of the motor, or, if necessary, their independent determination is a very simple matter. The vertical ordinate of any point on either curve represents the current flowing into the motor, while the horizontal distance from the left-hand side of the sheet shows upon one curve the speed in miles per hour at a fixed voltage, and upon the other curve the horizontal effort in pounds which the motor will exert at the tread of the driving wheels when it is taking this amount of current. In order to determine the effort exerted by a car equipment it is necessary only to place an ammeter in circuit with the motors, and the reading of this, by comparison with the curves of the particular motor, gives us immediately the horizontal effort exerted by the motor at that instant, and approximately the speed. For example, supposing the motor in question to be geared with 24 teeth in the pinion and 58 teeth in the axle gear; the two curves marked "Gearing 58-24" in Fig. 1 show that when 30 amperes are flowing into the motor it will exert

a horizontal force, at the rim of 33-inch driving wheels, of 120 pounds, and the car will be moving at 42 miles per hour with 500 volts at the motor terminals. If the ammeter reading is 125 amperes, the same curves show that the effort exerted is 1320 pounds and the speed is $18\frac{3}{4}$ miles per hour. I say "approximately the speed" because the speed is dependent upon and almost proportional to the voltage at the motor terminals, and, as this fluctuates in electric railway work anywhere from 10 to 20 per cent., the speed cannot be determined without a simultaneous determination of the voltage. The torque exerted by the motors, however, is independent of the voltage; a certain current flowing through the coils of the motor will develop a definite pull at the armature shaft. I am aware that this statement contradicts a popular impression that a series-wound motor requires more current to drive a car at a low than at a high voltage, but it can be shown that the statement is absolutely true and that the popular impression is the result of mistaken, or rather misinterpreted, observations.

To return, however, to the question with which we started: How many pounds of pull does it take to move a train of a certain weight at a certain velocity? The formulæ which steam railroad engineers have developed have been in some cases based on hundreds of experiments, but, on account of the widely differing nature of track and train construction, the formulæ differ widely from each other, both in their form and in their final results; and, without intending to criticise the older branch of railroad engineering, I wish to collect here some of the best known of these formulæ and compare them with readings which we have obtained in electric railroad work.

(1) One of the oldest formulæ with which I am familiar was proposed by Mr. D. K. Clark, and is of the form $F = \left(8 + \frac{V^2}{178}\right) W$. V being the speed of train in miles per hour and W the weight of train in tons of 2000 pounds.

(2) Another formula, proposed by Professor Rankine, is of the form $F = \{ (5.35 + .268 (V-10) \} (T + 2 E)$. T being the weight of the train behind the engine and E the weight of the engine and tender. Professor Rankine's formula is that of a straight line, the resistance being proportional to the velocity above 10 miles per hour and a constant quantity below that. He also recognizes the importance of the head resistance, the "pace-making" effort of the engine.

(3) A formula proposed by Mr. W. H. Searles, and based on his experiments, and which, Mr. Wellington says, has a "wonderful

range of application to all speeds, conditions and classes of trains," is of the form $F = 4.82\ W + .00535\ V^2\ W + .0004783\ V^2\ E^2$.

(4) The most complete and accurate experiments with which I am familiar were made by Mr. A. M. Wellington.

The method used by Mr. Wellington, the gravity method, is free from the disadvantages I have quoted, and is as nearly theoretically perfect as we can expect in work of this nature. The method is based on the well-known principle that a body moving down a frictionless inclined plane will have acquired, at any point of the incline, the same velocity as if it had fallen freely through a perpendicular distance equal to the vertical projection of the inclined path traversed.

Given a train moving at the top of a grade with a measured velocity, if steam is shut off and the train allowed to slide down the grade, with gravity as its only accelerating force, and if measurements of the velocity are made at various points on the grade, the difference between these velocities and the theoretical velocity due to the difference of levels will give us a measure of the retarding forces experienced by the train. Mr. Wellington went perhaps further than any one else had gone. He divides the frictional resistance experienced by a moving train into:

(*a*) Rolling friction, or the friction of the journals and that between wheel and rail, a quantity independent of the speed.

(*b*) Head resistance, or the atmospheric resistance experienced by the first car of the train.

(*c*) Side resistance, or the resistance offered by the atmosphere to the several cars of the train.

(*d*) Oscillating resistance, or increased journal and rolling friction, depending on the speed.

The formula he develops takes account of all these, and is of the form $P = 4\ W + .26\ V^2 + .03\ V^2\ G + .005\ V^2\ W$; G in this formula representing the number of cars in the train.

For sake of comparison I have collected in the table below the results of about twenty observations, which I consider the most trustworthy of those I have been able to get. These observations have all been made on interurban cars running on T rails and over a level track at a uniform speed.

In this table the first column gives the number of cars composing the train, the second the total weight of the train, the third the speed in miles per hour and the fourth the traction coefficient or horizontal effort in pounds per ton of train, as calculated from the current consumption. The succeeding columns give the results of the formulæ which I have already quoted, applied to these

particular cases. The formulæ themselves are repeated at the foot of the table.

TRAIN RESISTANCE.

Comparison of Observation and Formulæ.

No. of Cars.	Speed of Train.	Weight in Tons.	Res. per Ton.	Clark.	Rankine.	Searles.	Wellington.	
1	25.9	20	23.5	11.7	18.	14.8	17.7	23.2
1	28.	21	22.	12.4	20.3	16.8	19.5	23.6
1	32.	20	25.	13.8	22.5	19.8	25.	24.4
1	34.	21	25.7	14.4	23.5	22.6	26.8	24.8
1	36.	21	28.3	15.2	24.7	24.8	29.6	25.2
1	43.	20	27.	18.3	28.4	32.4	42.	26.6
1	45 5	20	27.7	19.6	29.6	35.4	46.	27.
1	47.	20	28.	20.3	30.5	37.8	49.	27.4
1	47.5	20	27.3	20.6	30.75	38.5	50.	27.5
1	40.5	20	25.	21.7	35.9	41.4	54.	27.9
2	27.	35	17.7	12.1	15.5	12.7	14.7	18.7
2	39.	35	20.3	16.5	20.5	21.5	25.5	21.1
2	40.	35	25.	17.	21.	22.	27.6	21.3
2	40.25	35	20.25	17.1	21.2	22.3	27.8	21.3
2	42.25	35	22.3	18.	22.	24.1	30.7	21.8
3	25.	50	16.	11.5	13.1	10.5	11.7	16.4
3	34.5	50	20.	14.6	16.7	15.7	18.8	18.3
3	37.6	50	18.5	15.9	17.9	17.7	21.5	18.9
6	31.8	95	18.3	13.7	11.2	12.25	14.	15.7

Clark $\left(8 \times \frac{V^2}{178}\right) \times W.$

Rankine $\left\{ 5.35 + .27\,(V-10) \right\} (T + 2\,E).$

Searles $4.82\,W + .005357\,V^2\,W + .0004783\,V^2\,E^2.$
(Head.) (Side.) (Oscillation.)

Wellington $4\,W + .28\,V^2 + .03\,V^2\,C + .005\,V^2\,W.$

Proposed $(18 + .2\,V)\,E + (7 + .2\,V)\,T.$

V=Speed in miles per hour.

C=Number of cars in train.

E=Weight of engine or motor car in tons of 2000 pounds.

T=Weight of trailer cars in tons of 2000 pounds.

W=Weight of whole train $E + T$.

It will be noticed that the formula of Mr. Clark is too low in every case to correspond to these observations. The common fault of the other three formulæ is that the velocity plays too important a part in them. At speeds in the neighborhood of 50 miles per hour their results are too high, and at 25 miles per hour they are too low. This is particularly the case with the formula of Mr. Searles and Mr. Wellington, where the velocity enters as the square.

I do not propose to base a formula on the results of about twenty experiments; but, as I have said, these observations are the most trustworthy that I have been able to collect, and it may be of interest to try to find a formula which shall combine their results more nearly than those which have already been proposed. By

plotting these results I have decided on the following formula as expressing, as nearly as possible, the results of these observations.

For a single-motor car weighing E tons, pulling trailers weighing T tons, the resistance in pounds due to the motor car is $(18 + .2\ V)\ E$, and that due to the trailers is $(7 + .2\ V)\ T$. The results of this formula have been worked out in the last column, and, by comparing them with the observations in column 4, they will be seen to give a very fair agreement.

As far as my own observations go, for ordinary interurban cars running on straight and level T rails, with roadbed of modern construction, the formula

$$P = (18 + .2\ V)\ E + (7 + .2\ V)\ T$$

expresses very fairly the train resistance between 25 and 50 miles an hour, and, while I do not mean to say that these experiments are exhaustive, I hope this statement may be of assistance to other observers in collecting and stating the results of their observations.

ACCELERATION.

The next question which demands our attention is the power expended in acceleration. How many pounds of pull does it take to give a certain weight a certain velocity in a fixed time? What accelerations are usually attained in practice, and what are the attainable and limiting rates of acceleration?

The answer to the first of these questions is mathematical rather than experimental. If a force P acts upon a mass W to produce acceleration, leaving out of account for the present the force necessary to overcome friction, the acceleration, F, will be equal to $32.2\ \frac{P}{W}$; forces and weights being expressed in pounds and acceleration in feet per second per second. In what follows it will be convenient to express acceleration in terms of the gain in one second of velocity measured in miles per hour, which we will write F_m; $F = F_m \frac{5280}{3600}$.

Transforming the equation above we get $P = \frac{F\ W}{32.2}$. Substituting for F, $P = F_m\ W\ \frac{5280}{3600 \times 32.2}$, or $P = F_m \times W\ 21.9$ and if $W = 2000$ pounds, we get the force per ton equal to the acceleration multiplied by 91.3, or pounds per ton $= F_m \times 91.3$.

The curves in Fig. 2 show the accelerations which are obtained in actual practice. Curve No. 1 shows a start of an eleven-car train on the Chicago, Burlington and Quincy Railroad, copied from data given by Mr. Wm. Forsyth in an article, "Tests of Locomotives in Express Service," published in the "National Car and Locomotive Builder," April, 1893.

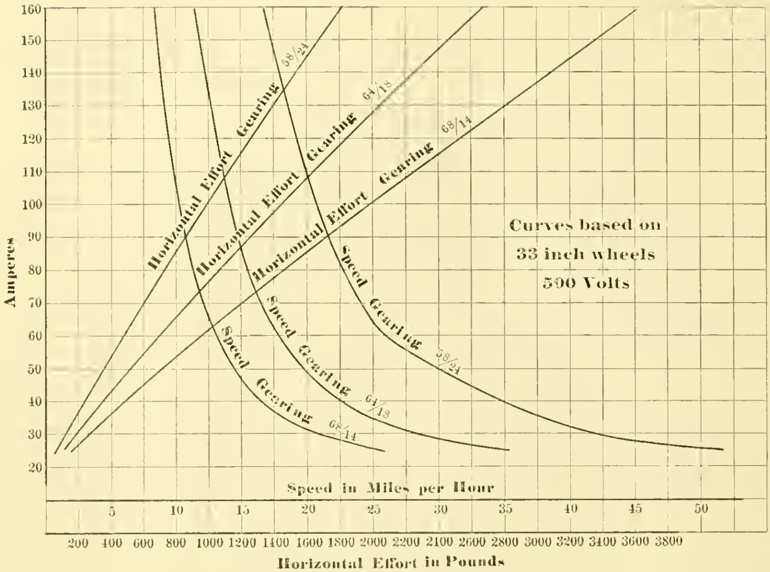


FIG. 1. RAILWAY MOTOR. SPEED AND TORQUE CURVES.

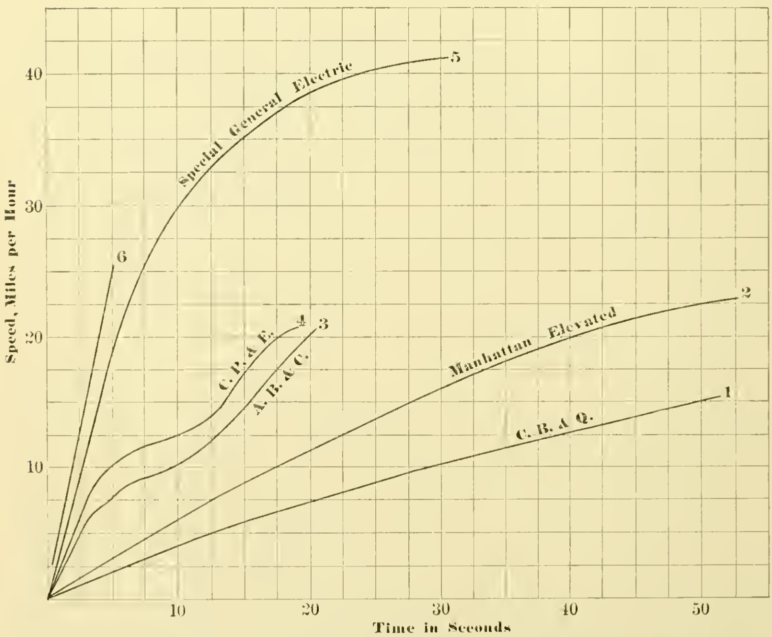


FIG. 2. ACCELERATION OF TRAINS.

Curve No. 2 shows the start of a Manhattan Elevated train, and is taken from an article by Mr. Geo. L. Fowler in the "Railroad Gazette," March, 1897. Curve No. 3 shows the start of an Akron, Bedford and Cleveland car. Curve No. 4 is a corresponding observation made on the Cleveland, Painesville and Eastern road.

Curve No. 5 is taken from an article by Mr. W. B. Potter, engineer of the railway department of the General Electric Company, and shows the starting curve of a car equipped by that company with a view to experimenting upon very high accelerations.

The following table shows the number of pounds per ton used for acceleration in the various starts shown in these curves, calculated from the acceleration by the formula derived above:

HORIZONTAL EFFORT

For Various Accelerations and Grades.

Roads.	A.	G.	H. E. per Ton.
C., B. and Q., steam	1		36.5
Manhattan Elevated, steam	2		55
A., B. and C, electric	3		183
C., P. and E. do	4		238
Special G. E.	5		348
Limit			470
Woodland Avenue		9%	180
Seneca Street		11%	220
North Hill		13½%	270

The limit of possible acceleration in railroad work is naturally fixed by the slipping of the driving wheels. It can be shown that the start represented in curve No. 5 is very near to this limit. It is generally acknowledged that the adhesion of wheels to rails is, under good conditions, one-fourth of the weight upon them, and under ordinary conditions one-fifth. If we assume, however, one-fourth, and assume moreover that the whole weight of the car rests upon the driving wheels, it will be seen that the limiting accelerating force is about 500 pounds per ton, and, allowing 30 pounds per ton for frictional resistance, we have about 470 pounds as the limiting acceleration. Curve No. 6 shows this limit. That such starts as this are not uncomfortable, if made smoothly, is testified to by the fact that we experience negative accelerations of comparable amounts upon our interurban cars without discomfort. I have myself noted a stop from 25 miles per hour within 90 feet, and from 41 miles per hour I have seen a stop made in eight seconds. As these represent a negative acceleration of 475 pounds per ton, it is evident that the rails were in pretty good condition, and that we had an adhesion of about one-fourth. I might note

that both these were emergency stops, and a little more sudden than ordinary. I am told by motormen upon our suburban roads that, with brakes in good condition, they can always make a stop from 50 miles per hour in five poles, or 450 feet, which represents a negative acceleration of 365 pounds per ton.

From these facts we may conclude that the limit of possible acceleration is fixed only by the adhesion of the wheels to the rail, or by the willingness of railway managers to provide extra power for the sake of increased schedule speeds.

GRADE RESISTANCE.

It is often stated, as an advantage of electric traction, that an electric car is able to mount steeper grades than a steam-driven train. This statement, while true, is often misstated, or rather misunderstood, by those who make it. The advantage does not lie, as many seem to think, in the electric current *per se,* and when steam railroad managers think it advisable to equip an 800-ton train with 8000 horse power in motive power the difference will not be as apparent as it is to-day. The force necessary to lift a train up a grade is the same fraction of the weight of the train that the rise of grade is of the horizontal length.

As an example of some of the grades we meet in practice, we may note that the Cleveland City Railway is operating on Woodland Avenue a grade of 9 per cent., and pulling trailers on that. The Cleveland Electric Railway is operating on Seneca Street hill a grade of about 11 per cent.; the A., B. and C. is operating on North Hill, Akron, a grade of $13\frac{1}{2}$ per cent. To compare these resistances with those ordinarily experienced in acceleration, the latter part of the table shows the number of pounds traction per ton of train necessary to mount such grades.

An inspection of the table shows that the tractive effort necessary on ordinary grades is comparable with that necessary for such acceleration as we ordinarily meet in electric railroad practice.

POWER CONSUMPTION.

Let us apply the data of the foregoing discussion to some problems, in order to determine the power expended in particular cases.

Let us take, as a first illustration, an ordinary city car, which, together with the equipment, will weigh about 12 tons. As may be noted any night after 12 o'clock, going out either Prospect Street or Detroit Street, the maximum speed which such cars attain on a level, after the period of acceleration is past, is about 20 miles

per hour. Applying our formula for train resistance, 18 + .2 V, the frictional resistance of such a car at this speed is about 22 pounds per ton, giving us a horizontal effort of 264 pounds necessary to propel a 12-ton car; and 264 pounds, at 20 miles per hour, is equal to 14 horse power. Assuming that the efficiency of such motors as are ordinarily used at this speed is about 75 per cent., this gives an input at the trolley of 18.8 horse power, or 14 kilowatts, which, at 500 volts, is equivalent to 28 amperes. This represents approximately the amount of current necessary to propel such a car.

As a second illustration let us consider an ordinary double-truck interurban car. The weight of car body and truck, empty, is about 15 tons. The motors ordinarily used for such a car weigh about 3000 pounds. We can estimate the total weight, including a two-motor equipment and a few passengers, at about 20 tons. These cars run upon a level at a speed of about 28 miles per hour. Applying our formula, we get 23.4 pounds per ton, or a total of 472 pounds horizontal effort necessary for propulsion. At 28 miles an hour this is equivalent to 35 horse power. Figuring the efficiency of these larger motors at 32 per cent. gives us 43 horse power, or 32 kilowatts input, which, at 500 volts, gives 64 amperes, or 32 amperes per motor, as the ordinary running current.

Another interesting question is, What should the starting current amount to in cars of this weight? If we take curve 3, Fig. 2, the curve of acceleration for the A., B. and C. car, we see that, at the maximum, as the acceleration begins to fall off (which corresponds to the point where the controller is entirely cut out), we have an acceleration amounting to 1.25 miles per hour per second. This is equivalent to 114.5 pounds per ton, or, for a 20-ton car, about 2300 pounds horizontal effort necessary at this point. As the speed attained with this pull is approximately 18 miles per hour, the motors are delivering about 110 horse power. Figuring the efficiency of the motors at 80 per cent., we get a total input of 138 horse power, or 103 kilowatts, which, at 500 volts, represents 206 amperes as the starting current.

As a final example, let us consider the cars of our latest interurban road, the Lorain and Cleveland Railroad. No tests on this road have as yet been published, but we are promised by the engineers a complete set of tests as soon as the road is in running shape. When such tests are published we shall have some basis for judging of the reliability of the figures above submitted. Such cars will weigh, empty, about 15 tons, or 30,000 pounds. They are equipped with four motors, which must weigh in the neighborhood

of 3000 pounds each. We can safely estimate the weight of car and equipment at 22 tons.

With these cars a speed of 35 to 45 miles an hour is common, and after having gone a mile or so from a stop they attain a speed of 50 miles per hour.

What current do the motors take to propel the car at this speed?

The train resistance on a level is $(18 + .2\ V)\ W$, and since, in the present case, W is 22 tons and V is 50 miles, we have 616 pounds effort necessary for propulsion. Now, 616 pounds at 50 miles per hour is equivalent to 82 horse power, which represents the output of the motors at full speed. For motors of this size we may estimate the efficiency at about 82 per cent. This means 100 horse power input to the motors.

As for voltage, a visit to the power house will show that a voltage of about 600 is carried, and that heavy feeders are used. We can, therefore, estimate that they get 550 volts at the motor terminals. One hundred horse power at 550 volts is 135 amperes. My estimate, based on the data given, is that it takes about 135 amperes to propel these cars after they have attained full speed.

Another interesting question is, How much current does it take to start these cars? If we are allowed to make some assumption, we can estimate somewhat nearly. These cars seem to me to gain speed at the start a little more slowly than do our ordinary suburban cars. Let us suppose that they start under an accelerating force of 150 pounds per ton, or a total effort of 3300 pounds. To this must be added about 23 pounds per ton for frictional resistance, making a total of 3800 pounds.

How much current, flowing through these motors, will produce a horizontal effort of 950 pounds per motor? To determine that it will be necessary to know of what speed the motors are capable at some definite voltage and at this torque. From the car windows we may note that a speed of 35 or 40 miles is very soon attained, but it is not until after we have traveled a mile or so that we reach a speed of 50 miles per hour. We will not be far from correct if we figure that the motor maintains an accelerating force of 150 pounds per ton up to about 25 miles per hour, and that then, as the controller is entirely cut out, the motors continue to speed up and the current falls off, together with the acceleration. An effort of 3800 pounds at 25 miles per hour is equivalent to 254 horse power. Assuming again the efficiency of the motors at 80 per cent., we get an input of 317 horse power, or 236 kilowatts.

At 550 volts this indicates a current of 430 amperes as the probable current during the period of acceleration.

In conclusion, let me repeat the statement I made in the beginning. It often seems that the equipment of a single car with motors of from 100 or 200 horse power is an unnecessary waste of power, but when we consider the weight of car and the loads under which we are operating, the rapidity with which we are compelled to accelerate these weights on account of our frequent stops and the grades which our ordinary highways compel us to climb, we see that ordinary mechanical principles justify the demands of practice for heavy equipments.

DISCUSSION.

Mr. W. H. Searles.—The experiments upon which Mr. Clark's formula is based were made in the earlier days of railroading and at velocities much lower than those to which we are now accustomed. The constant term is higher than it should be, as proved by later experiments, and this, no doubt, led to the use of too small a coefficient of V^2. The formula is quite satisfactory for a velocity of 20 miles an hour, but is too high at lower speeds, and too low at higher speeds. It is intended for a whole average train, not for a car alone nor an engine alone. Mr. Clark, in his Manual, recommends adding 50 per cent. to meet unfavorable conditions of track or weather.

The later formulas, in three terms, are adapted to a wider range of cases, such as light or heavy trains, high or low speed, etc., but still they are expected to apply only to steam locomotive trains. The conditions of a self-propelled motor-car, with or without a trailer, are so different that we may well look for a new formula to apply to them.

The internal resistances of a locomotive engine absorb a large amount of energy, which, therefore, does not appear as tractive force at the drawbar. Yet this resistance is all counted in and helps to make up the total resistance of the train. The internal friction increases rapidly with the load and with the velocity, and it is this, as well as the atmospheric resistance and the oscillations of the train, that makes the total velocity resistance so high at high speeds.

The resistance offered by modern cars, singly or in train, is pretty well established. The resistance of the engine is not so well defined. It is often assumed at 10 per cent. of the total resistance, and may amount to as much as 16 pounds to 30 pounds per ton of the engine.

The formula proposed in this paper has two distinct terms, one for the motor-car, the other for a trailer. The terms are similar in form, and differ only in the constant. If we suppose the trailer to be loaded until it weighs the same as the motor-car, then T=E, and if we then subtract one term from the other we have (18—7) E=11 E as the internal resistance of the motor equipment, or 11 pounds per ton of the motor-car. This, according to the formula, is constant at all velocities, and it probably is more nearly constant in fact than the internal resistance in the locomotive.

But the constants appear to be too high, as in Clark's formula, and the line of the formula not sufficiently inclined. At 5 miles per hour, at which the resistance of a passenger car is known to be a minimum of not over 4 or 5 pounds per ton, the formula gives (7+1) T=8 T, or 8 pounds per ton; and for the motor it gives 19 pounds per ton. We need experiments on a greater range of velocities, all the way from 5 to 60 miles an hour, before building a formula for motor-cars; but it would seem that if the present formula were written thus:

$$P=(14+0.3V)\ E+(3+0.3V)T$$

it would better meet the general conditions, while agreeing equally well with the few instances cited in the paper. It is hardly possible, however, for a right line formula to represent all the facts. There should be, in my opinion, at least one term involving the square of the velocity.

Mr. L. M. Sheldon.—What effect has the ground return on the cars? In the motors we sometimes find a heavy amperage, but a great deal of it is lost in the rails.

Mr. Dodd.—That is due to high resistance in the ground return, which simply lowers the voltage at the motor terminals.

Mr. Sheldon.—Do you measure the torque by the amperage?

Mr. Dodd.—There is a popular impression that when the voltage is lowered the car takes more current, but it does not. The amount of current required to pull a car over a level track is exactly the same at 300 volts as at 500. There is a certain amount lost in overcoming the resistance of the trolley and of the rail.

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DEEP BRIDGE FOUNDATIONS, ATCHAFALAYA RIVER.

BY C. H. CHAMBERLIN, MEMBER OF THE LOUISIANA ENGINEERING SOCIETY.

[Read before the Society, August 8, 1898.*]

THE purpose of this paper is to give such facts in regard to the work on the Atchafalaya Bridge as came under the writer's notice, and the excuse for it is that in foundation work experience is a good teacher. A study of facts as obtained from former accomplishments, either of ourselves or others, may help us in present work.

The Atchafalaya Bridge was built in an alluvial section, and the unusual depth of the piers was made necessary by reason of the instability of the soil when acted upon by the river current.

The piers of which this paper treats, being those two nearest the east end of the bridge, were sunk by the pneumatic process, which has so largely superseded other processes on account of the certainty of its application in any class of material.

It is fortunate this method was adopted from the beginning of the work, because the obstructions encountered in sinking would have been more formidable by any other method.

It may not be out of place to remark that the Atchafalaya River, in high water, is a swiftly flowing stream, as compared with other streams in the alluvial portions of Louisiana; and the reason is readily understood. Waters coming down the Red River or down the Mississippi River may divide near the mouth

*Manuscript received September 29, 1898.—Secretary, Ass'n of Eng. Socs.

of the Red; a portion may go down the Mississippi, while the other portion may go down the Atchafalaya. The waters of Red River, therefore, and of the Mississippi above the Red, have two ways to run to the Gulf of Mexico, one the lower Mississippi itself and the other the Atchafalaya; but sea level is reached by the Atchafalaya in about 140 miles from the point of separation, while it is only reached in about 310 miles by the Mississippi. The fall in these distances is the same, being about 53 feet during high water.

The effect of this current on the banks and bottom of the Atchafalaya is shown by the increased and increasing cross-section.

From a stream of very moderate capacity it has, within the memory of men now living, enlarged so that in flood stages it discharges about half a million cubic feet per second.

I have it from reliable authority that the estimated cost of a railway bridge at West Melville, made from the first surveys, was only $75,000, and this, too, at a point about 800 feet above the present bridge and dangerously near the place where the bed of the river is now 120 feet below sea level and the width from bank to bank some 1500 feet.

This enlargement of the river has made work upon the bridge constant and expensive.

Prior to 1894, and since abandoning the transfer boats, the Texas and Pacific Railway Company has maintained its crossing at West Melville by using one 303-foot draw span and two 250-foot fixed spans, all of iron, and trestle approaches at each end. At one time there was a 150-foot Howe truss on the east side, but the sliding bank rendered its foundation unsafe and the trestle was again rebuilt and constantly worked upon. There has also been a Howe truss on the west side, where a 250-foot steel span now is.

The original iron structure rests upon cylinder piers which reach to about minus 84 of the river gauge, two cylinders at each pier, except at the pivot pier, where there are seven. These cylinders are filled with concrete, and those of each pier are braced together at the top. At the east end of the draw, at what we now call Pier II, the attempt was originally made to put in the usual cylinder pier, but the sliding bank broke off the tubes before they were completed and further work of a permanent character was not again attempted till the fall of 1894, when the contract was let to put in a set of cylinder piers at this place and also a set 250 feet farther east, and erect upon them a steel span of modern design.

Mr. A. J. Tullock, proprietor of the bridge works, himself an accomplished engineer, had to assist him Mr. Alfred Noble, of Chicago, as consulting engineer, and Mr. M. A. Waldo, now with

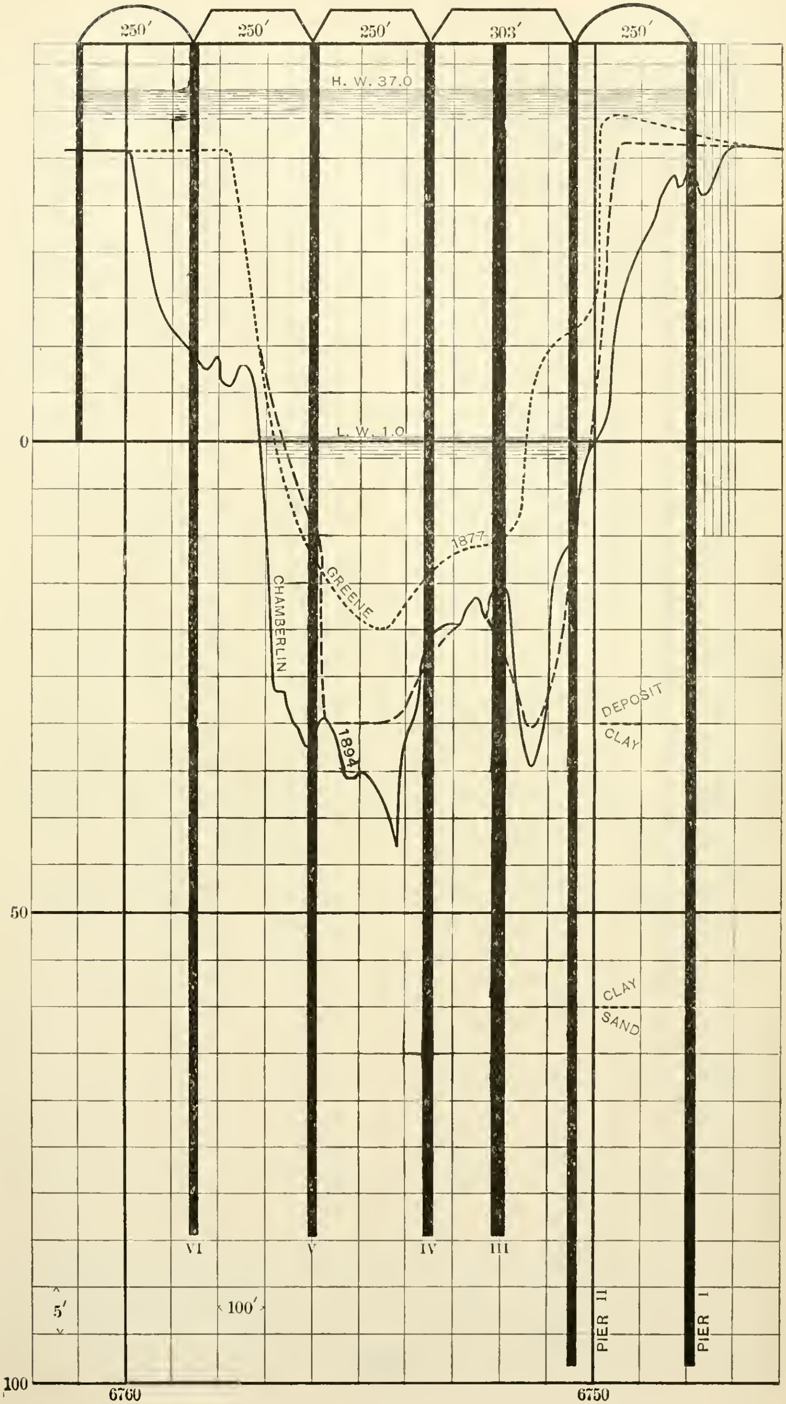

250′
250′
250′
303′
250′
H. W. 37.0
L. W. 1.0
0
50
100
1877
GREENE
CHAMBERLIN
1894
DEPOSIT
CLAY
CLAY
SAND
VI
V
IV
III
PIER II
PIER I
5′
100′
6760
6750

FIG. I.

the Union Bridge Company, as resident engineer upon the works. To these gentlemen the credit of the design and execution of the work is chiefly due. To the last-named gentleman particularly the writer is indebted for valuable data.

For convenience, all elevations are referred to the river gauge, the zero of which is minus 1.09 feet mean gulf level.

As a preliminary precaution test borings were made close to the pier sites, and showed that from the surface of the ground to minus 30 feet was ordinary river deposit, with quantities of brush and logs; from minus 30 to minus 60 was a blue mud or clay, soft near the top but very firm farther down; from minus 60 to minus 100 was pure sand, fine near the top but getting coarser as it was penetrated, and having in it occasional pebbles.

These borings were verified while the pier work was in progress, and it is worth our while to give at least a passing notice to the material through which they were made. The instability of the river deposit above the stratum of clay has been the cause of all the trouble in maintaining the approaches.

It is needless to expand here upon the natural laws governing a caving bank; suffice to say that all the sliding of the bank at this point has taken place *in* the deposit above the stratum of clay. This is proven by the fact that in sinking Pier II, as soon as the ordinary deposit was passed through and the mud stratum entered, the lower sections of the original piers put down in 1882 were encountered, and had to be broken up and brought out through the air locks. They had moved but little if any after they were first crushed.

Preparatory work consisted in getting the materials and plant on the ground, in providing for the safe passage of trains during construction and guarding against accidents due to sliding banks.

A machinery barge was provided, and was equipped with the necessary boilers, air compressors and pumps and an electric light plant. Old rails were furnished to add weight to the cylinders in sinking. These, when used, were stood on end on the inside of the inner cylinder, just above the air lock; and some also were cross-piled on a frame resting on the top of the cylinder, but in both cases so arranged as not to interfere with the passing of men or material by them.

Fig. 1 shows the profile along the axis of the bridge in 1882, when the original work was done, and in the fall of 1894, just before the new work was started. For comparison the cross-section made in 1877 is plotted. It also shows the location and designation of the piers. The bridge crosses the river in a nearly

due east and west course, the right-hand side of the profile being east.

The present paper has reference to Piers I and II, which were constructed during the winter of 1894 and 1895. The span resting on them was also erected at that time. The span shown at the west end was added three years later. When work was begun

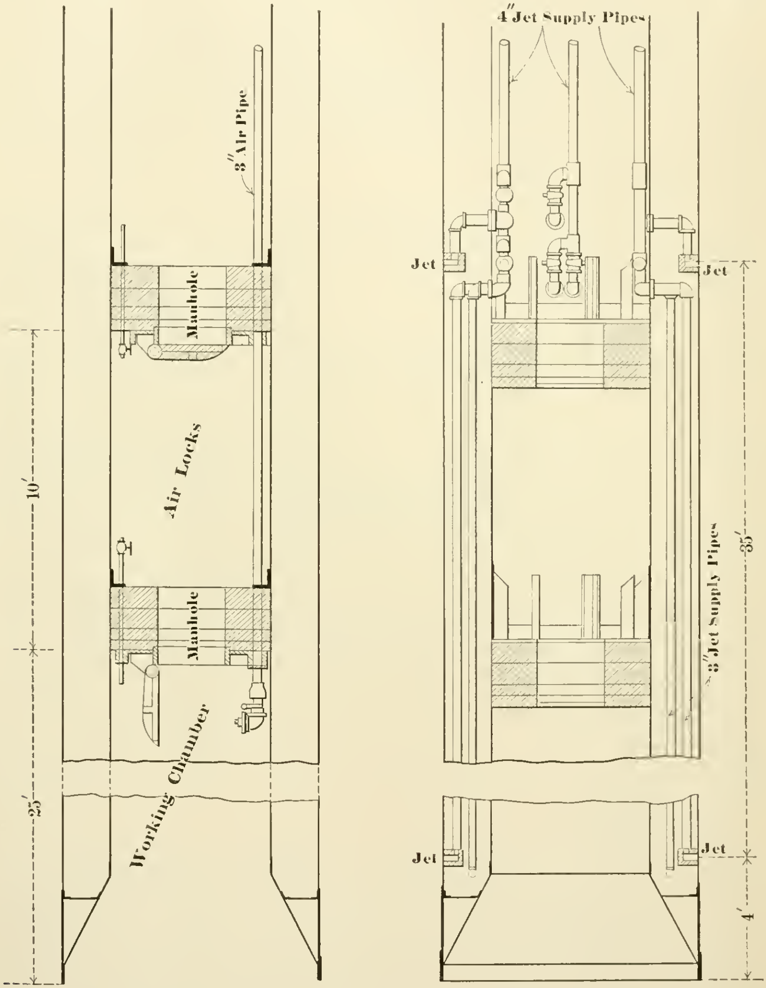


FIG. 2.

there was a pile trestle from the east bank to the draw span, a distance of some 330 feet. Work was first begun on Pier II, and the pier had to be located directly under the east end of the draw.

Foreseeing that any temporary foundation, for supporting the end of the draw and the track, put close to the sinking cylin-

ders, would be disturbed and rendered unsafe by reason of the subsidence of the material around the cylinders during sinking, a plate girder of special design, 50 feet long, was put in, having its center over the pier site. Its ends rested on pile bents. This furnished a temporary rest for the end of the draw, and the trestle was made to connect with its east end, beyond the reach of any dangerous settling of the material.

At Pier I, higher up the bank, this girder was not used, but a span of 28 feet was made of the standard wooden stringers used on the road. These rested on ordinary bents of piling. Whenever they settled the track was blocked up to its proper height to allow the safe passage of trains.

To illustrate the sinking of material: Just after the false work at Pier I was put in it was decided to locate this pier about fifteen inches farther east than first intended, so as to admit of setting the bed plates of another span upon it when the widening of the river makes another span necessary. This movement, slight as it was, caused a very marked difference in the amount of settling at the east end of the 28-foot temporary span over that at the west end.

Pier I was located near the eastern edge of the part of the bank which was liable to cave, as was shown by the warning fissure in the sand running parallel with the river. Trouble with this pier from a caving bank was therefore not anticipated. But for Pier II it was thought best to grade off a part of the stratum of sand which overlies the clay, giving it a slope at which it would stand at low water; because a sliding bank would have caused much trouble in holding the pier in position, if it could have been held at all. Accordingly an excavation was made, with a water-jet, extending from near Pier I to the edge of the bank in the direction of Pier II. It was gratifying later to see that, while both above and below the banks did cave, at the pier no perceptible sliding took place.

Figs. 2 and 3 give an idea of the construction of the piers. Each pier consists of two cylinders, 8 feet in diameter, braced together near the top. Each of these cylinders has an outer and an inner shell, which are held concentric by four webs or stiffeners riveted to each. The inner cylinder is 5 feet in diameter, and was the working shaft. They are in sections of 5 feet, but were added to the sinking pier in sections of 10 feet. Both are made of $\frac{3}{8}$-inch steel plates. The inner shell extends from the bottom of the cylinder to above the ground line, but does not reach the top of the pier. Four feet above the cutting-edge the inner shell begins to

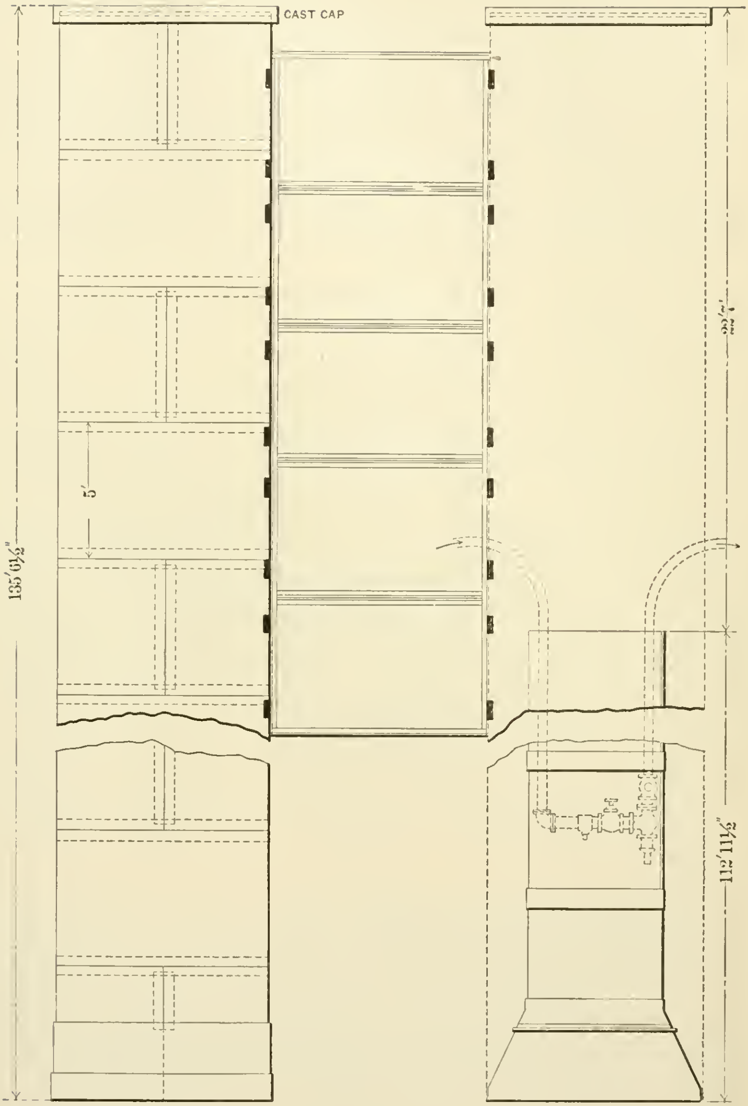


FIG. 3.

increase in diameter going downward, joining the outer shell at the cutting-edge, as shown in Fig. 3.

The space between the outer and inner shells was concreted as soon as the section was added to the cylinder and riveted. This added materially to the weight needed in sinking.

Each 5-foot section was fastened to the sections above and below it by horizontal bands placed on the inside of the outer shell, and on the outside of the inner shell, together with the stiffeners spoken of before. These were all securely riveted together.

A ladder ran up the inside of the inner cylinder. An elevator had been provided to work in the shaft above the locks, but it was not thought expedient to use it.

In Fig. 3, from the cutting-edge upwards for 25 feet, was the working chamber. The air pipe and the pump pipes shown in Fig. 2 entered this chamber. Immediately above the working chamber were the air locks. These were composed of an upper and a lower wooden ring or diaphragm, fitting closely to the inside of the inner shell and securely fastened to it. Each wooden ring was 2 feet thick vertically, and was composed of four thicknesses of oak securely fastened together. The manhole through the center was something over 2 feet in diameter, and was provided with a heavy cast iron door opening downward, having suitable hinges and fastenings. There were four pipes passing vertically through the wooden diaphragm,—viz. the 3-inch air supply pipe, which terminated just under the lock; the 4-inch water supply pipe, for the sand pump; the 4-inch discharge pipe, for the sand pump, and small pipes with suitable stopcocks for equalizing the air pressure. These locks were made with special care, and were overhauled on the ground, to make sure that they were air tight.

The right-hand side of Fig. 2 shows the position of the sand pump.

Fig. 4 shows the pump itself, which is readily understood as acting on the principle of the steam siphon.

Fig. 3 shows an important factor in decreasing the friction between the cylinder and the material surrounding it,—viz. the water jets. These are worth an extended description, as they greatly facilitated the work, not only in sinking the piers but in guiding them.

Four feet above the cutting-edge was a row of holes through the outer shell running horizontally around the cylinder; 35 feet higher was a similar row. These were the jets. All or only a part could be worked at once, as judgment might dictate, except that in this case there was only pump power sufficient to work one full

set at a time. Separate pipes with suitable valves led to each quadrant of a set, so that a part could be operated independently of the other part. The position of the cutting-edge and of the working top of the cylinder was accurately determined every morning, or as often as necessary; and if it was intended to move the cylinder in any particular horizontal direction the jets on that side would be made to run the longer time. It would also often be necessary during a settle to assist the jets and force the top out of position by wedging against a framework built around the cylinder above ground. In this way the cylinder would be temporarily inclined out of its vertical position to be straightened up during some subsequent settle. Of course, as the piers went

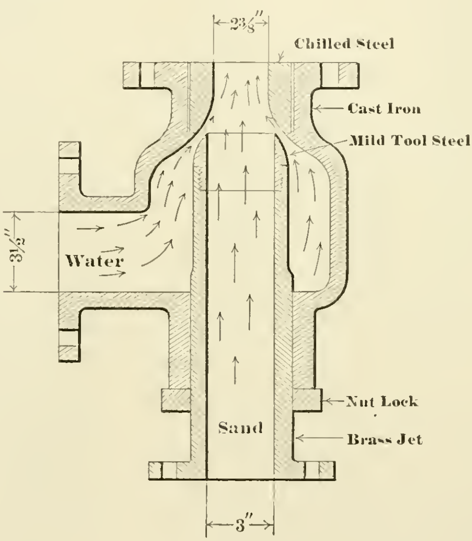


FIG. 4.

deeper into the ground the more difficult they were to control, and it was only to be expected that the cutting-edges would stop at last somewhat out of position, the greater care during the final settle being given to getting the tops in their true places.

The value of the jets in reducing friction was demonstrated on this work in this way: In sinking Pier II they were not needed, and were not used till the cutting-edge was below minus 60, when it was found that the lower jet holes had become plugged with sand and could not be opened; while at Pier I they were used at every settle, whether needed or not, and the difference in the ease with which the two piers sunk was quite marked.

The four progress diagrams herewith give a correct history of the work. The observations from which they were made were taken at eight o'clock each morning.

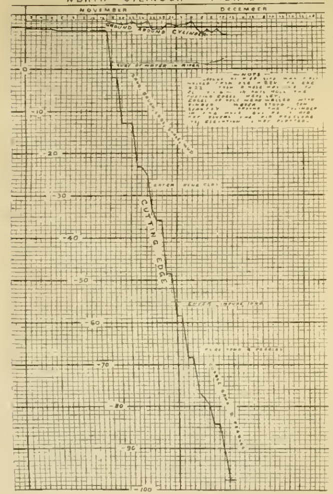
Of one peculiarity it is well to make mention. The air pressure required to keep the water from rising in the working chamber was always equal to or slightly in excess of the weight of the river water displaced, when the cylinders were well on their way down. This goes without saying at Pier II, which was located in the river water; but around Pier I there was always a hole of water varying from 2 to 6 feet in depth, the surface of which was from 9 to 15 feet above the river while the work was progressing, and yet the stage of the river governed the air pressure.

In making a settle the material would ordinarily be pumped out of the working chamber nearly to the cutting-edge. Then the pressure gang, consisting of three men, would come outside. The jets would be started and run for about two minutes; then the air would suddenly be reduced to two-thirds, or sometimes one-half, of its working pressure, when the cylinder would sink. On resuming work the working chamber would be found partly filled with the material through which it was passing. This would be again pumped out and the sinking process would proceed as before. After the cylinder had stood for twenty-four hours or more the first settle would only be a few inches, but subsequent settles, made without any delays due to concreting, or adding sections, or to other causes, would each amount to 2 or 3 feet. When everything was working nicely the operation of the jets alone, without reducing the air, would sink the cylinder several inches. The amount of material pumped out was probably three or four times greater than the actual displacement of the cylinder. This was due to drawing material down from the outside.

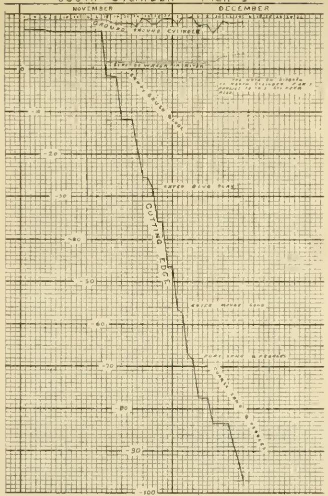
When the cylinder reached its final resting-place the pump pipes and the jet pipes above the locks were removed and the operation of sealing begun. Concrete was taken through the air locks in sacks into the working chamber, and was handled and tamped there by the pressure men. In this way all of the space was filled, except just where the lock door swung, and this space was filled with grout after the door was closed. From the lower door to the top of the shaft there was nothing to interfere with rapid concreting, and the work was continuous till finished.

Work now being all above the water line, the air pressure was taken off and the building up of the cylinder to its proper height to receive the cast iron cap was carried to completion. This cap rests on a bed of rich mortar, and is raised above the cylinder about an inch, so that it does not rest upon the shell.

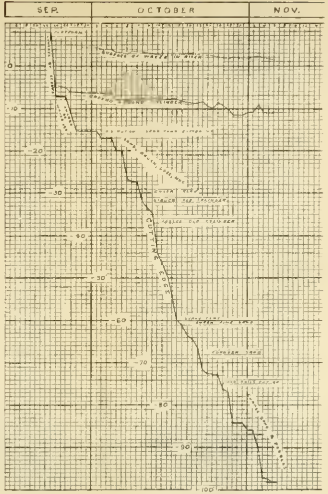
NORTH CYLINDER — PIER I



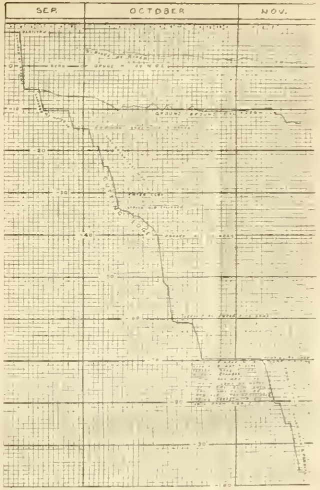
SOUTH CYLINDER — PIER I



SOUTH CYLINDER — PIER II



NORTH CYLINDER — PIER II



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The physiological effects upon the pressure men, while quite interesting, were not unusual in work of this kind. Of course, the human system is more or less taxed to withstand the effects of compressed air, and members of the pressure gangs would occasionally experience excruciating pains on leaving the working chamber, but there were no fatalities. As the working pressure was increased the hours making up a day's labor were decreased. While the maximum pressure was used, three hours, divided into shifts of one hour each, constituted a day's work.

Any person on entering compressed air experiences first a sensation of great heat; then a painful tingling in the ear is a warning that artificial means must be used to equalize the pressure on the inner and outer sides of the ear drum, else results fatal to that membrane may ensue. Air may sometimes be forced through the ducts leading to the inner side of the ear drum by the act of swallowing. If this does not suffice it may be accomplished by deflating the cheeks as much as possible, having the nose and mouth closed. Failing in this the attempt to enter the working chamber had best be abandoned for the time. The danger attributable to this cause is only present while passing through the locks. The abundant supply of oxygen in compressed air has rather an exhilarating effect upon a person entering a caisson, but labor there is quite exhausting, and there is an opposite depressing and chilling effect upon leaving it.

An idea of the frictional resistance while sinking, though unsatisfactory, may be arrived at.

Take for example the north cylinder of Pier II, on November 13. The depth immersed was 92.85 feet. The air pressure was 40.2 pounds per square inch. This makes the reaction on the cylinder due to air pressure 130 tons. Subtracting the reaction from 295 tons, which was the entire weight of the cylinder with its load of concrete and rails, we get a net weight of 165 tons supported by friction. This, reduced to pounds and divided by 1971, the number of square feet of surface in contact, gives us 187 pounds per square foot as a frictional resistance at the time. But the friction was greater than this, because the cylinder would not move unless the jets were started or the air pressure was reduced. It must also be remembered that air bubbles were constantly arising from under the cutting-edge and from leaks, causing more or less disturbance of the material surrounding the cylinder and reducing the friction.

It would be interesting to know what the friction on these piers is after all the disturbances of the soil have long since ceased.

THE FRASER ELECTRIC ELEVATOR.

By A. E. Brooke Ridley, Member of the Technical Society of the Pacific Coast.

[Read before the Society, June 3, 1898.*]

The employment of elevators in buildings is of comparatively recent origin, and was rendered necessary, in the first place, by the desire of people to spend as little of their energy as possible in non-productive work; and, in the second place, by reason of the aggregation of people in cities. This rapidly increased the price of land, thus inducing an increased height of buildings. Elevators then became necessary as a means of access to the upper stories. As speed was still a secondary consideration, the hydraulic plunger system obtained much favor, consisting of a water cylinder extending vertically into the ground to a depth equal to the height to which the elevator was intended to travel, the elevator cage being placed on the top of the piston rod of this cylinder, which was raised by the admission of water under pressure applied underneath the piston.

The continued increase in the height of buildings rendering this system impracticable, a modification was adopted by placing the cylinder horizontally, the movement of the piston communicating around overhead sheaves with ropes attached to the elevator cage. When the length of the cylinder became extreme a two-, three-, or four-multiple transmission was employed.

In all these types the elevator descends by its own weight, but recently an elevator company has reversed this, causing the cage to run up by its counterweight and descend by the pressure of water, the cylinder being vertical.

To secure the pressure required to lift a given load at a given speed, either city water is used direct or a tank of water is placed on the roof of the building or a pressure tank is provided. On account of the expense and of the insufficiency of pressure, city water is seldom used, but in either of the other cases the water, being used over again, must be pumped by power either to the roof or the pressure tank.

Electricity here found its first employment. The steam pump hitherto employed required a boiler and an engineer, and was very wasteful of steam, while an electric motor could operate a suitable pump and, when fitted with an automatic arrangement to start and

*Manuscript received August 29, 1898.—Secretary, Ass'n of Eng. Socs.

stop when necessary, constituted an important economy in operation.

All hydraulic elevators, however the power to operate them may be obtained, have one inherent disadvantage,—viz, that the capacity of the cylinder and the pressure of the water has to be sufficient to raise the elevator at its rated speed with its maximum load; and, however light the load, the same amount of water must still be used, as the cage can rise only as the cylinder is filled with water. Among minor difficulties may be mentioned the amount of space the apparatus takes up, the liability of the water to freeze in the pipes in cold climates and the cost of keeping the cylinder water-tight.

With a view to eliminating the above-named limitations, the direct electric elevator was introduced, it having the immense advantage of consuming power only in proportion to the work performed; and, as is usually the case, the line of invention took the form of operating known apparatus by electricity. Thus, an ordinary mining hoist was connected to an electric motor by belting or gearing, worm-gearing being at the present time generally employed; and this machine is colloquially known as the worm-gear or drum type of electric elevator.

Thus far inventors had plain sailing, but their difficulties increased in arranging for the control of the speed and the reversal of the motors, as, for electrical reasons, it was necessary to energize the field before the armature and then to admit the current very gradually to the armature and yet fast enough to get the elevator in motion rapidly. Next a brake had to be provided, and removed when the power given to the motor was sufficient to lift the load and not before; and, finally, the motor had to be reversed in order to reverse the direction of motion of the elevator. Further, all this had to be done automatically by a simple lever or button in the cage, so as to relieve the elevator attendant as much as possible. These various combinations are operated by means of solenoids and magnets, and these in modern machines operate very reliably. When it is considered how subtle a force is electricity, it is wonderful what good service is rendered by elevators of this character.

This class of machinery has a speed limitation of from 200 to 300 feet per minute, and this is not on account of any want of power. To explain, the elevator has to attain its full speed between floors, and to stop within a very few feet. It is manifestly impossible to use electric current for the purpose by reversing the motor, as the electricity has to be shut off and all connections reversed,

the opposing current admitted to the magnets first, then gradually to the armature. The motor has to stop and start again the opposite way. The only practical method, therefore, is to cut off the current and stop the elevator with a powerful brake.

To illustrate, a 2000-pound elevator must have a brake sufficiently powerful to retain the elevator at rest when loaded to its full capacity, and provided with sufficient surface to bring the elevator to rest promptly at this load. It will, however, be quite apparent that, if the elevator has a load of only a few hundred pounds, it will be brought to rest abruptly, causing discomfort to passengers. Further, the length of distance that the elevator will travel before the brake brings it to a standstill will vary, according to the speed at which it is traveling and the weight that is being controlled. These two factors vary constantly in practical use.

The correct determination of the conditions has to be left to the operator, and in the exercise of his judgment he shuts off the current and applies the brake at a certain period before reaching a landing. Up to a speed of 300 feet per minute, with the elevator working, as it generally does in practice, on a fairly constant load, the operator can stop at landings without much difficulty; but if the elevator is unexpectedly loaded up it is liable to slide a foot or two past the stopping place.

We now come to elevators designed to duplicate high speed hydraulic service, and operating at speeds of from 300 to 600 feet per minute.

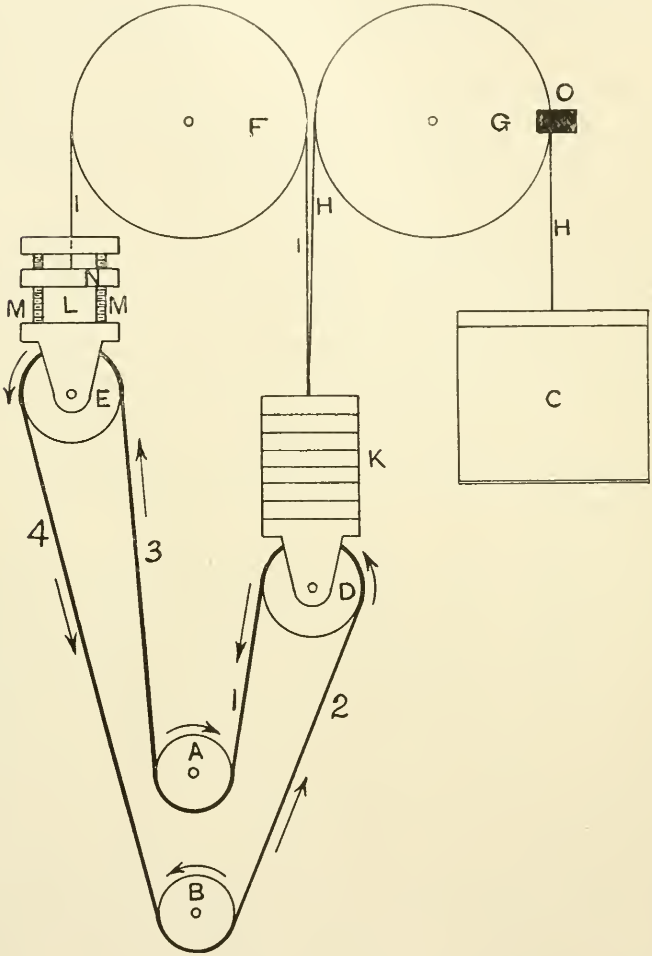
Of these there are three systems, the Sprague-Pratt, the Ward-Leonard and the recently invented Fraser elevator.

The Sprague-Pratt elevator is a counterpart of the hydraulic machine from the car to the water cylinder, but the piston and cylinder are replaced by a screw, which, being rotated, draws up a nut along its length. The rotation of this screw is effected by connecting one end of it directly to the armature of a motor.

The details of this system have been very completely worked out. Ball bearings have been placed between the nut and the screw, the balls running in the thread of the screw. The controlling apparatus is operated by a pilot motor, and this motor controls not only the resistance but also the action of the brake. The button or lever in the cage starts the motor and also operates the main current switch. The car is sufficiently counterweighted to descend by gravity, even when empty.

The motor uses current only while raising the load; in descending the weight of the car revolves the screw and the con-

nected armature. To prevent the elevator from dropping too fast, the field of the motor is excited from the line and the armature terminals are short-circuited through a resistance. This resistance can be varied at the will of the operator, and the speed of the car can thus be controlled. A brake is used to hold the load, but not



Fraser Electric Elevator System.

in stopping the car. While this type of machine can be controlled much better than the ordinary form of worm-gear, for the reason that the machine is always taking current while hoisting and generating current in lowering, the enormous pressure and consequent friction on the thrust bearing and nut, when geared for high speed, greatly increase the cost of operation.

The disadvantage of this machine lies in its complicated controlling devices, requiring skilled attendance, and the large amount of electricity required to bring these elevators rapidly from rest to full speed; for, as the cage descends by gravity, the electricity has to carry up not only the load but a portion of the weight of the car in addition. The direct result of this sudden call for current lessens the pressure in the electric mains, causing what is known as a "wink" in all electric lights operating from the same wire, unless either the elevators are run from independent machinery and wires or the electric wires are very large in size. It is well to mention that the elevator companies disclaim any responsibility for the troubles of the central station man.

With a view to overcoming these difficulties, Mr. Ward Leonard invented a system of control, employing a motor generator which was always running and an elevator of the usual drum type construction, the motor of which was operated by this motor generator, the controller in the car increasing or decreasing the voltage of this generator by means of resistance in the field, thus changing its potential and in consequence the speed of the motor. This arrangement, while it accomplished to a great extent the results desired, requires the use of an additional generator for each elevator, making the initial expense very great and increasing the cost of operation.

Mr. E. M. Fraser, of this city, recently invented and perfected an electric elevator which obviates nearly if not all the disadvantages above mentioned; and I ask your permission to give a somewhat detailed description of this machine, as the prognostications of the elevator have been so completely verified by a practical working of the apparatus. I also think it will prove of considerable interest, as this is the first complete description that has been given before a technical audience.

In the Fraser elevator all gearing of any kind has been eliminated and the motors are never reversed; the brake is used only to hold the car, and for no other purpose. The speed of the elevator is controlled entirely by the strength of the field magnets, and it can be run at any speed it would be desirable to run an elevator.

By this system the best hydraulic service can be duplicated, and the elevator can be operated at any intermediate speed between rest and full speed at the will of the operator.

The apparatus is controlled entirely electrically when running both up and down; and the elevator can be brought to rest

and its direction reversed, allowing only sufficient time to avoid discomfort to passengers.

Its control is operated by making use of the small field current of the magnets, the main armature current being never broken under load. This obviates the most troublesome part of the mechanism usually employed. The operating mechanism consists merely of a field magnet controller and an armature resistance controller.

The system is a modification of the well-known differential principle, as exemplified in the "Weston" differential chain block; with the difference that, instead of having two driving sheaves or pulleys of larger and smaller diameter run at the same speed, two separate pulleys of the same size are run at different speeds. In one system the difference of circumferential speed is obtained by having the pulleys of different diameters, in the other peripheral speed is changed by changing the relative number of revolutions. Two electric motors are used, connected by an endless transmission rope, each motor working independently; and by varying the speed of either armature the car can be made to go up or down.

In the figure, A and B represent two motor pulleys, and C the car; D and E are two idler pulleys, which are free to move up or down in suitable guide strips or posts. The guide pulley D is fastened to the bottom of the counterweight K, and the guide pulley E is fastened to the frame L. This is arranged with two threaded rods, M M, so that the manila ropes, 1, 2, 3 and 4, can be tightened or loosened by screwing the cross-piece N up or down on the threaded rods M M. The tightener L and the counterweight K are connected together by an iron cable I, which passes over a large iron sheave F placed at the top of the well-hole directly over the traveling pulleys. To the top of the counterweight K several iron cables are fastened, and from the counterweight they are run over a large pulley G and fastened to the car C. As the counterweight K moves up or down, the movement is transmitted through the cable H to the car, which is thus moved coincidently with the counterweight.

A very powerful clutch O is so arranged as to hold the sheave G in the event of the current being cut off from the motors A and B from any cause whatever. This clutch is never used to stop the car, except in case of accident.

The action is as follows:

Pulleys A and B revolve in the direction indicated by the arrows, and the manila ropes, 1, 2, 3, 4, move in the direction indicated by the arrow points.

The motors are started, and, so long as they both run at the same speed, the rope simply moves over the various pulleys freely and nothing further takes place.

But if the speed of A is increased and it is thus made to run faster than B, then the part of the rope at 1 moves down faster than the part 2 moves up; and to be able to do that and not slip on the pulleys A and B, D must also move downward. As D is free to move up and down in guides, it does so, and the greater the difference in speed between the two pulleys A and B the faster it moves. When they are brought to the same speed the pulley D and the connected counterweight stop their downward motion.

But suppose now that we speed up the pulley B and make it revolve faster than the pulley A. Then the part of the manila rope 2 will move upward faster than the part 1 moves downward; consequently there must be some slack rope at D. Looking at the rope which passes over the idler E, we find that the rope at 4 moves down faster than the rope at 3 moves upward. The pulley E must move downward to allow this to happen, and, as the pulley E is connected with the pulley D by means of the wire cable I passing over the sheave F, D must move upward and so take up all slack rope, thus keeping the manila transmission ropes, 1, 2, 3, 4, always at the same tension.

The car C, which is connected by the cables with the counterweight K, is made to move fast or slow, or to stop, by simply varying the speed of either motor pulley.

The cage of the elevator is suspended by iron ropes and counterweighted in the usual manner; but for the endless running gear independent manila ropes are employed, these ropes being $\frac{5}{8}$ inch in diameter and seven or more in number, according to the load the elevator is constructed to lift.

The motors are never reversed, consequently no reversing switch or mechanism is needed. When the motors are started they do no work other than to move the transmission ropes over the traveling idlers, consequently the controllers do not have to take care of an excessive starting current; and, as the current is cut off when the car is at rest and the motors running idle, the contacts do not have to break a heavy current at high voltage. The requirements call for a starter or automatic rheostat of very simple construction.

As it is not necessary to start the motors gradually and without jerk, only three stops or contacts are used. The first contact cuts in the armature current through a resistance, and also cuts in the field direct; the second contact cuts out part of the resist-

ance, and the third contact cuts out all the resistance and connects the two armatures directly across the line. The resistance is cut out automatically as the armature increases its speed.

The field coils of each motor are wound in sections, and the ends of each section are connected with a number of buttons in the car controller by a flexible cable. The operator, by moving a lever in the car, cuts out the different sections at will, and so speeds up the armature of either motor, according to the direction in which he moves the lever. To raise the car he moves the lever in such direction as to cut out the sections in the upper motor. To lower the car he simply moves the lever in the opposite direction and cuts out the sections in the field of the lower motor. When he wishes to stop the car he brings his lever to the center. This equalizes the speed of both motors and the car stops.

The automatic starter is so arranged that when a latch is lifted by the operator in the car the motors are started automatically, and when he drops his latch the current is cut off and the motors stop. The operator can stop and start the motors each trip, or he can keep them running as long as he holds up the latch. To prevent stopping the motors while the car is in motion the latch is so arranged that it will drop only when the lever is in the center.

As there is nothing to prevent the car from moving up or down when the motors are stopped, a powerful brake is used to grip the sides of the main overhead sheave, over which pass the cables supporting the car and counterweight. The brake is released by the current and applied by a powerful spring. In the event of the current being cut off, from any cause whatever, the brake is applied. Ordinarily the current is cut off from the brake at the same time the latch is dropped in the controller and the motors stopped. It is impossible to apply the brake while the car is in motion, except by the cessation of the line current; and it is used only as a matter of safety, and not as a means of control.

From the foregoing description of various electric elevators, the essential requirements of a perfect elevator will be understood as follows:

First. Safety.

Second. Ability to fulfill all conditions required at high speed.

Third. Simplicity and reliability of mechanism.

Fourth. Avoidance of discomfort to passengers.

Fifth. Small starting current.

Sixth. Ability to run at any intermediate speed up to full speed.

Apparatus that will fulfill these conditions will duplicate the best hydraulic service in the country at greatly lessened cost and increased satisfaction to all concerned, and will ultimately replace all other types where electricity is available under the well-known law of the survival of the fittest.

DISCUSSION.

Professor Keith.—Though it is hardly pertinent to the subject of electric elevators, I may mention one or two other hydraulic elevators that have been operated, or that could be operated, by accessory electric power in pumping. One of those to which I refer is the telescopic ram hydraulic elevator. More than twenty years ago there was put into the post office building in the city of New York an elevator that obviated the use of a very long plunger. The plunger was made telescopically, so that the depth in the ground which had to be excavated was only one-third or one-quarter of the depth which would have been necessary without this telescopic device. The pistons then ran out as a telescope. Whether that elevator is now in use or not I cannot say.* Then there is the pneumatic hydraulic elevator, which consists of a chamber in which the air is compressed by pumping the water into the chamber and producing the pressure in that way, instead of pumping to the roof of a building or to other elevations.

As to the control used in the Sprague elevator, I think it was in 1892 that the Electrical Engineering Company, with which I was engaged at that time, put the motor at the top of Echo Mountain, in the neighborhood of Los Angeles. I understand that that motor is in use still. It had a device the equivalent of that by which the motor would, upon the descent of the car, be turned into a dynamo, and thus act as a brake.

I would ask Mr. Ridley how he provides against the almost inevitable sparking at the commutator and brushes, due to the change of the strength of the field of the motors in the regulation of Mr. Fraser's elevator. I have been very much interested in the description of the Fraser elevator, and it would seem to me to be a very feasible, practical system. The question that arises in my mind is the possible slippage of the ropes running around the drums or pulleys of the two motors. That may, I presume, be provided against by proper construction of the pulleys.

Mr. McNicoll.—With reference to the slippage of the ropes in the Fraser elevator, mentioned by Professor Keith, they are

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*Similar elevators were used for a time, perhaps as long ago, in the freight station of the Pennsylvania Railroad in Philadelphia.—Sec'y, Ass'n Eng. Socs.

run on sheaves turned with V grooves on the rims made with an angle of less than 45°, and, so far, there have not been less than seven ropes run over them in each case. The ropes on elevators that have been running two years show little or no wear, of which the small amount of work they do is the cause. You will note how the balance weight is attached to the car. The car of a large passenger elevator weighs about 2000 pounds, and the balance weight is made of an equal weight with the car, plus 50 per cent. of the load that it has to handle. We find that in the average travel about half of the passengers go up and half come down. So, with this arrangement of overbalance, the load we actually raise by the two motors is equal, in the case I instanced, to only 1000 pounds. That is, if we want to raise an average load of 2000 pounds we have an overbalance in the weight of 1000 pounds, and we use 1000 pounds lifting capacity on the motor to raise the load of 2000 pounds. It is readily seen that the force exerted by the motors is only half of the load it is desired to carry. The weights are carried on all-wire cables, and there are six of those cables used. As they run over large sheaves, there is little or no danger of their breaking. The transmission ropes used are either cotton or manila, and under maximum conditions of load each rope does not carry over 200 pounds, so there is very little strain upon them. The overhead brake in the Fraser elevator is very readily set. It is made on the principle of the Westinghouse air brake; that is, it is always on unless the current holds it off. The elevator can move only when current is applied to the motors, and the moment the motors stop the brake is applied—instantly.

Professor Keith.—Then the current necessary to hold off the brake is the minimum current necessary to run the motors in doing any work?

Mr. McNicoll.—Yes. When the operator raises the lever, in order to move the elevator one way or the other, that movement releases the brake, and the motors can run at their normal speed without moving the car. If there was an extra heavy load, a load heavier than the car, it would have a tendency to move down, or if the car and load were lighter than the overbalance weight it would have a tendency to move up. So the slightest movement of the lever will throw more current into either one motor or the other to hold the load stationary. In other words, the loads can be handled and controlled electrically on the car without the use of a brake. If there was an excessively heavy load on, of course more current would have to be put on the holding motor.

Professor Keith.—Then the question of running several ropes parallel, five or six or seven, and keeping them of uniform length, is one that I should think would have to be considered.

Mr. McNicoll.—They are put on very exact as to length in the first place, and they are all separate ropes, so that if one or two or three, or even four, were to break the balance would still be holding and would be sufficient to hold the load.

Professor Keith.—Yes, but some of them might be slacker than others, even if they were all put on of exactly the same length.

Mr. McNicoll.—That is true. But there is a tightener that takes up all that. Some of the ropes are naturally running with more slack than the others, but from the V shape of the groove they are held in place and by the aid of this tightener the slack is taken up. One very fine feature in the Fraser elevator is that the load can be run at a speed of as high as 700 feet per minute, and it can be run and reversed in the twinkle of an eye; and raised and lowered so that, with the eyes shut, one would hardly notice the direction in which the car was running, so neatly is the movement accomplished with the electrical current, no brake being applied. The change is brought about merely by a change in speed of the two motors.

Professor Keith.—Is the change made in one motor or in both? Do you increase the speed of one and decrease the speed of the other at the same time?

Mr. McNicoll.—At the same instant, yes. That is under the control of the controller in the car.

Mr. Richards.—In what are called electrical elevators the current and apparatus simply transmit energy as do other means, such as steam, air, water, shafts or ropes. There is no such thing as electric power at this time, but the conducting wires form an ideal means of conveying power within buildings where it would be undesirable to erect steam engines. Under that system the steam engines can be centralized in some suitable place.

As to a complete electrical plant within a building, including the original motive power, I must express doubt as to any advantage over hydraulic apparatus, especially when there is special service of the latter for that purpose, as in a number of cities in England and elsewhere, including Australia, where filtered water is laid on at a pressure of 700 to 1000 pounds per inch, thereby reducing the dimensions and cost of the machinery.

No city is better adapted for such a service than San Francisco, but, after several futile attempts, we are without a system here; but we have in its place the electrical transmission, one that

is complete in respect to an efficiency greater than can be attained by a hydraulic system, also with some other characteristics that are desirable. It is perhaps too soon to assume that it is to become general to the exclusion of other methods, but certainly its progress has been phenomenal this far.

Mr. Ridley has run somewhat into error respecting the waste of water by using a constant volume, irrespective of duty. There is one example here, a very notable one, in the Palace Hotel, where there were five hydraulic elevators erected twenty years ago, designed by Mr. G. W. Dickie, our past president, that consume water approximately as the loads are raised. The work was divided, I think, between four separate rams or pistons, with a fifth one to act as a counterweight for the carriages or platforms.

The rams were progressively thrown into action according to the load, and the water was distributed by balanced valves corresponding to the most advanced practice of our day; and I venture the statement that, all things considered, it is one of the most remarkable examples of hydraulic engineering in this country. Some of these elevators have been changed to attain greater speed. How much of the old plant is in use I am not able to say.

In respect to the Fraser system of operating elevators, I will say, as a mechanic (and that is the only phase of the subject with which I pretend to deal), that there are several obvious advantages not only in the mechanism or gearing, but also in its electrical control. Between the rotative motor and the reciprocal movement of the cage the inventor has introduced a gearing that commends itself in many ways. It is not new in mechanics, but it is novel in its application. The fact that the motors revolve continually in one direction is certainly a very important advantage.

From several points of view, I am disposed to criticise the Sprague-Pratt elevator system. I do not see that a screw movement is necessary, and still less why ball bearings are introduced. The primary motion is rotary, and a winding drum is certainly as good a device as the Armstrong pulleys for multiplying motion. There are only a few of these elevators here, and the number is not likely to increase. Ball bearings are suitable when the pressure is light, but under heavy strains balls become the most effectual agent for pulverizing known to the arts. The chilled iron shot used in cutting granite are an illustration. These balls will soon cut a groove in the screw threads and nuts, and the time will soon come when that portion of these machines will be relegated to the scrap pile.

Some time ago I called at the Parrott Building, where eleva-

tors of this kind are in use, but could not gain admittance to examine them. I could, however, see from a guard fence around the machines that the screws were abraded by the balls.

Such devices survive in proportion to their merit. I do not remember that any have been erected except in the Parrott Building and in the Safe Deposit Building. They were made and erected with the utmost care, and I have reasons to believe, as Mr. Ridley has pointed out, that the electrical elements are extremely complicated.

The circumstances that the contractors retained control of the machines for a long time after their erection warrants this statement, and I doubt whether any one can find out much about the operation and present state of the machinery.

I think elevators could have been furnished here for less money, of an equally efficient character and to have given equal satisfaction. I do not know what the future may bring about, but up to this time San Francisco has a foremost place in this branch of engineering work.

There is first the differential hydraulic system of Mr. Dickie, before referred to. A little later on Mr. Milliken introduced his system of single tubes for underground rams. Then Mr. Hinkle's hydro-pneumatic system was extensively applied. Then the overbalance, which divided or reduced the capacity of the motive power nearly one-half, had its origin here. The Moore clutch for belt-driven gearing may also be mentioned. Then came the hydro-steam system of Mr. Hall, the water compensating and traction systems by the same inventor, and then the Fraser system described in Mr. Ridley's paper. Some of these things have spread widely over the world, we may say in modified forms, but originating here.

I may also mention the cable car system, which is only an inclined elevator system in so far as steep grades are concerned.

Mr. Behr.—I would ask Mr. Ridley what pressure per square inch has been allowed on these nuts of the Pratt-Sprague system; what the length of the nut is in regard to the screw, and whether any calculation has been made with regard to the stretching of the screw under pressure. There must be a difference of pressure per square inch between the two ends of the nut. When calculations are based on a uniform pressure it will be found that some of the nuts would heat; that is, speaking of nuts without the ball bearings.

Mr. Barth.—I would ask Mr. McNicoll to explain how it is that to put up an electric elevator, say of the Fraser type, to lift

the same weight as any of the worm-gear machines, costs so much more money than it does to put up a worm-gear machine.

Mr. McNicoll.—In answer to that question, I will say that one is a mechanical proposition, and there is simply no limit to the work of the screw with small single motors and high gearing. The Fraser proposition, on the other hand, is entirely an electrical and not a mechanical one, and in order to lift heavy loads these motors have to be made of a very large size to do the work properly. There is no gearing employed. Consequently we find that to lift say 2500 pounds with the Fraser electric motors we have to have two motors, which, when stood one on top of the other, stand as high as I stand. That is the reason for the high cost. With the smaller motors we lift lighter loads. We use the power direct from the two pulleys on the motor shafts.

Professor Keith.—As both motors move in the same direction, when one motor is increased in speed and the other one is decreased, is there not a tendency from the increase of speed of one to increase the speed of the other as well? What provision is made so that the other may actually decrease in speed? I suppose that that is effected by the change in the strength of the field, as before said. Now, does that change in the strength of the field have to be made greater than would otherwise be the case to decrease it to a given percentage in its speed?

Mr. Fraser.—The motors are plain shunt-wound motors, and the shunt-wound motor cannot be run faster than it wishes to go; that is, the moment it is run faster than it wishes to go it turns into a dynamo and generates current. When Mr. McNicoll said we had to have large motors, as is the case, in order to act direct, that does not mean that we use more current than would be used with the other patterns. The large motor takes a large amount of current, but it does not take it all from the power house. The power is transmitted through the rope from one motor to the other. One motor acts as a dynamo, and all the current we really use is the difference between what one motor uses and what the other generates. As we have found in practice, one motor will generate from 50 to 75 per cent. of the total power required. That is the reason why the current is large, that one motor runs as a motor and the other is driven like a generator.

In regard to sparking, we use a very powerful field on the motors, and when they are run at their maximum speed they are running with an average strength of field; and when they are running very slowly the field is saturated, so it does not spark under any condition. With this system we do not start the motors

under load. They are started perfectly free. Consequently the sparking on starting is reduced to almost nothing.

The controlling apparatus that transmits this current to the motor is very simple. The armatures are always revolving when the current is cut off, and consequently there is no arcing on the controller when the current breaks. A switch that is carrying electrical current of heavy amperage and high electro-motive force gives an arc when the switch is opened, and the more current there is the hotter the arc. Any elevator whose motor is started under load suffers from this disadvantage. Suppose the elevator is started upward and that it goes a foot above the floor. It takes an enormous amount of current to start the elevator with the load, and it has moved only a foot. Then the current is broken, and the process has to be repeated every time the elevator is moved. In that way this harmful arcing occurs. We have obviated that difficulty in this system by never stopping the motors with the load on. The motors are always running, the car is always stopped before the current is cut off, the current is reduced to two or three horse power and the voltage between contacts is, at most, about ten volts when the controller breaks the current, whereas in the other style of machinery you must break from 0 to 100 horse power.

Hitherto the great objection to the electric elevator has been the controlling apparatus. It is always causing trouble. If the least thing gets out of order it stops the elevator. We have tried to obviate that in this machine.

Professor Keith.—The motors are placed in parallel, are they?

Mr. Fraser.—Yes.

Professor Keith.—Suppose the normal revolutions, when the elevator is idle, are 1000. What increase of speed would be required for raising the load at the maximum speed? Would it be 2000 or 1800, or what?

Mr. Fraser.—The normal speed of the motor is 225. The speed of one of the motors is reduced to 175 under load, while the other one is speeded up to 600 or 800 revolutions. This gives a car speed, with a 15-inch pulley, of from 600 to 700 feet per minute.

The President.—The whole question of passenger elevators, as has been stated, is of very recent origin. There are several here who can no doubt remember the whole history of passenger elevators. They have been invented and placed in buildings since I have been connected with building operations.

The first passenger elevator of any kind that I ever saw was

in Boston in 1869. It was considered a novelty, and it was a matter of speculation as to whether they would ever become of general use. The first passenger elevator in San Francisco was, I think, erected in the early part of 1872 or the latter past of 1871, when one was put into Bradley & Rulofson's photograph gallery, on Montgomery street, a little cage about 3 feet by 4 feet. The first ones in Boston were steam elevators, and in the early seventies, up to 1875 or 1876, nearly all the development in passenger elevators was in the line of steam-driving machinery, crude generally, and the rope winding on drums. Mr. Richards says that it was nineteen years ago that this system was incorporated in the Palace Hotel. I feel quite certain that in 1876 I saw this hydraulic system at work in the Palace Hotel. It was a very successful apparatus, a very perfect piece of mechanism. From that time on the development of passenger elevators was in the line of hydraulic elevators. I think Mr. Hinkle was one of the first to use the horizontal hydraulic cylinder for running passenger elevators. But, as we all know, that was the method that was taken up and developed, developing the horizontal and vertical cylinders into the multiple rope and traveling cross-head, and increasing the speed thereby to almost any point desired. Other forms of elevator were abandoned generally for the hydraulic apparatus, which, during the past twenty years, has been very fully and perfectly developed. The machine that has been mentioned in the New York post office building was a three-section telescope machine, but it did not run very long. It was put in, I think, in 1875. About that time, or a little before, say 1873 or 1874, developments were made in hydraulic elevators. One was a counterbalance system, in which there was a great bucket to receive water at various stages. It received a volume of water, which was poured into it to counterbalance the weight of the elevator; and it would be received and discharged at every floor level. That was not successful. In the way of screw mechanism, I remember seeing an elevator with two vertical screws, one on each guide-post. It was not successful, as Mr. Richards predicts of the Sprague-Pratt elevator.

When it comes to electrical development and the principles that have been applied to electric elevators during the last seven or eight years or more, we see some of the same stages of development that we have seen in steam elevators. Perhaps the most successful, up to within a short time, of this class of elevators has been an application almost exactly like the original steam drum,

driven by a screw and worm-gear, only driven by an electric motor instead of by steam engines in the building.

With reference to the Sprague elevator, of which Mr. Richards says he does not see what the screw is put in there for, I see clearly what the screw is for, and I do not know how he would accomplish the object in view without it, which object was to carry the cross-head pulley of several ropes that must travel horizontally. It does not occur to me that any better device than the screw could be arranged. But what Mr. Richards says about the ball bearings is certainly true, and can be seen on the elevators running in the Parrott Building. They do crush and grind on the screw. The fact that they require a great deal of attention is vouched for by the case of the Safe Deposit Building elevators. In that building boilers and engines and dynamos were put in. Then the power was shut down entirely, and power was taken from the electrical company. Their engineer was discharged, but it was absolutely necessary to have the engineer there to take care of the elevators. So they must have the services of an expert engineer, although they make no power there. They require a great deal of power, too.

The elevator that has been brought before us to-night is a production of the Pacific Coast. As Mr. Richards says, this city has been wonderful in the line of inventions and improvements, not only in passenger elevators, but in other mechanisms. Mr. Fraser's machine dispenses with some of the greatest objections to electric elevators, such as that of suddenly stopping and rapidly starting a piece of machinery, and breaking the current and reversing it. All that is a shock to any machinery, and especially so to electrical apparatus, to which it is sooner or later fatal. I do not wish to be put in the light of advocating or advertising this Fraser elevator, but I will say this: I examined very closely, and with a great deal of interest, the first one that was put up as a sample machine. A change of speed from the highest speed going up to that going down was made so quickly and so evenly that with one's eyes shut he would not know when he stopped going up and commenced to go down. There is no shock at all. On the strength of my satisfaction with the elevator that was put up for inspection, I departed from my usual rule of not trying a new thing, and put in two elevators, I think the first two commercial elevators of the Fraser type ever put in. I am now about to put in three more in the most important building into which I ever had occasion to put elevators.

While no one else has brought up any objection to it, I will

state here the only objection that appeals at all to my mind, or that I am able to discern, and that is the use of manila ropes, or cotton ropes, or of any other inflammable ropes. I would like to see that rectified. I do not see how it can be done, but it is not a pleasant thing to know that the transmission of the power of your elevator is with material such that if there were any accident or carelessness, and if fire should be applied to it, it would be very quickly destroyed. Possibly that objection could be obviated by saturating the ropes with non-combustible solutions. It would not be fatal, perhaps, if the rope should take fire when the elevator was in use, but it would be a very desirable thing if that possibility did not exist.

Now, Mr. Ridley, we should be glad to hear you answer the questions that have been asked.

Mr. Ridley.—In reply to Professor Keith, I will say that there is no more liability to slippage in the ropes of the Fraser elevator than there is in any other rope transmission machine. It follows the same rule. In a grooved pulley of given diameter one rope will pull a certain weight, two ropes will pull twice as much, and ten ropes will pull ten times as much, and should a rope break from any cause the other nine will still hold the load.

This answer applies also to any unequal straining of the rope. As far as I know, if a strain comes upon one rope at a given time the others relieve it when they are stretched equally. Then, in addition to that, any small difference that may exist is taken up by the pulley and weight at the top sheave shown on the diagram.

The question of motors has been gone into very thoroughly by Mr. Percy, and, as he says, that is one of the very best things in favor of the Fraser machine. In the case of the old style motors, where there was not a continuous action, the breaking of the circuit caused the controlling apparatus to arc, and you were obliged to have carbon contacts which are gradually destroyed. Of course, you can put in new carbons whenever required, but you must have a man to do it.

With regard to the high pressure hydraulic, I do not see that the increasing of the pressure advances the cause of hydraulic elevators, except that, as has been said, you use a little less water. The contention that I made was that whatever hydraulic elevator is used you have to use an equal quantity of water, whether your load is light or heavy. It is this point that the direct electric elevator gets over.

With the exception of the Palace Hotel elevators, I know of very few that have been made with a similar construction, on

account of its complication. But it was a wonderful piece of engineering at the time it was made, as I think we all allow.

As regards the details of the pressure between the bolts and the screw on the screw type of elevator, no data has hitherto been obtainable, and I think that the only means of ascertaining will be by personal investigation.

It has been asked why the Sprague-Pratt, the Fraser, and the Ward-Leonard should be any dearer than the other elevators. In reply, I will say that that is not the case. The Sprague-Pratt, the Fraser, and the Ward-Leonard, and any other high grade elevator cost all about the same price, and you can no more compare one of them with the ordinary worm-gear elevator than you can compare a triple expansion engine with a simple Westinghouse. There is no comparison whatever between elevators that are used for high grade service and the other class of elevators. Then again, if you get an elevator of the cheaper class to raise 2000 pounds it will not raise 2000 pounds all the time. It will be of sufficient efficiency to get through the test, but its average efficiency will not be over a few hundred, and it goes along very unsatisfactorily if the duty is severe.

Mr. Percy spoke of the combustible ropes. I think it is quite possible that non-combustible rope may be used, although it has not yet been tried. Mr. McNicoll, dealing with the practical part, will probably know what experiments have been or are being made in that direction. But as regards the danger, there is no danger, as far as I can see, from the use of a combustible rope. Suppose that by any chance the rope should burn. You have a brake that is always on, and your elevator is just the same as any elevator.

The President.—But the brake does not act while the current is on. Suppose the rope burns while this is the case?

Mr. Ridley.—Then you have your safeties, and it would be the same if the overhead sheaves broke.

Supposing some of the manila rope were burning. There would necessarily, if the car was in operation, be an operator in the car, and by placing the controller in the center the current would be shut off and the brake put on. That would entirely do away with the objection.

Mr. McNicoll.—I would like to state that we had a practical illustration of that when the Phelan Building caught fire a few weeks ago, and burnt the fifth floor and gallery of one end of the building. The elevator itself carried up the fire patrol and all the firemen, and ran for fifteen minutes after the fire started, until

the sheave timbers were nearly burned through. Then the chief engineer told him to go down and open his switches and turn the current off, so there would be no danger. The whole top of the elevator was burning for probably five minutes before it was shut down. These ropes and the counterweight and other parts are generally placed off in a compartment on one side, where they are enclosed and protected more or less from the direct fire that would pass up in an elevator shaft. Another point is that the cage stands in any position, and when the ropes are placed and passed over the sheaves there is no connection between it and the motors. The overhead brake holds the car stationary. Again, not only will the safety catch stop the car on coming down, but upon going up also. On all electric elevators, when there is an overbalance, the danger is just as great, and probably a little greater, that the car will run away going up as in going down. In this safety catch the brake works either way equally well. It has been tested dozens of times.

Professor Keith.—I would like to call attention for the moment to an elevator of which there are quite a number in London, and that is an elevator that is continually going up on one side and down on the other. There is a series of platforms, and an engine is running the elevator continuously. You step off from a platform at the risk of limb, etc., but the risk is very small, as you can walk up the stairs about as speedily as the elevators work there from story to story. There are quite a number of them in London. There are very few, if any, fast moving elevators in the whole city. In fact, there are many buildings three, four, or five stories high in which there are no elevators whatever. It would be probably cutting too much into the conservatism of the people of Great Britain to put in an elevator that would run as fast as those in the Mills Building, in this city, for instance, even after they became so advanced as to have a building ten stories high.

The President.—In some of their hotels they have elevators that will carry you upstairs on application at the office, but you cannot have an elevator to bring you down.

Mr. Richards.—I have had occasion recently to go back over the history of hoisting machines, and the first elevator of which there is any record was made in 1841 by John G. Bodmer, a Swiss engineer in the City of Manchester. He made one to carry his men and freight in his works at Manchester. The machine moved at a fair rate of speed, and was a complete success.

TEST METERS FOR BOILER PLANTS.

By Lehman B. Hoit, Member Civil Engineers' Club of Cleveland.

[Read before the Club, August 12, 1898.*]

The requirements which suggested the use of a measuring machine, or, as it is now termed, a water meter, previous to the introduction of water works plants, are rather indefinite. With the installation of steam-actuated pumping machinery for distributing water to private buildings, manufactories, etc., the value of such a machine became apparent. The enormous increase in the consumption of water by those who formerly regulated the amount they required per day only by the facilities they had for obtaining it soon taxed the pumping machinery beyond its capacity. Habits of waste were encouraged and established under the popular impression that the water supplied was as free as air. The permanent expense of construction and distribution and the question of annual cost were lost sight of until the distributing mains became inadequate, and the pressure for fire protection fell below the point of safety. It was soon learned that merely estimating the consumption of water was disastrous, and it became necessary either to establish a water rate for each and every class of consumer or to resort to a rigid system of measurement. The policy of applying water meters, either as restrainers of waste or adjudicators of value, was adopted by many of the water works corporations, when it was agreed that the proper way to distribute water was to measure it.

It will be admitted by all who have given the matter any considerable attention that a good and reliable water meter must fulfill a great number of exacting conditions, and that the varying services to which meters are applied include a number of requirements.

First of all, a water meter must be accurate under all circumstances,—that is, it should register, with a reasonable degree of accuracy, the amount of water delivered at the various rates of flow, from the maximum capacity of the service pipe to a rate so small as to discourage attempts on the part of the consumer to obtain water without paying for it.

Any variation in the head or pressure should not affect its accuracy. Every gallon of water passed by the meter must produce a corresponding and registered motion in the meter. If on this

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point it is not well-nigh infallible, it is useless to talk of other advantages.

The degree of accuracy should be reasonably permanent; that is, the meter should not be subject to serious deterioration by wear, or affected by sediment or other substances contained in the water, to such an extent as to cause any change affecting its accuracy. Sudden opening and closing of meters should not induce any error in registry.

It must not obstruct the flow or cause serious loss of effective head or pressure. In other words, the meter must be nearly frictionless, and yet so well fitted as to run and register almost on drops. It must be constructed with few moving parts, and these so arranged as to render the possibility of derangement very remote. The parts must be constructed of the best material, selected with reference to their resisting the action of all kinds of water met with in everyday practice.

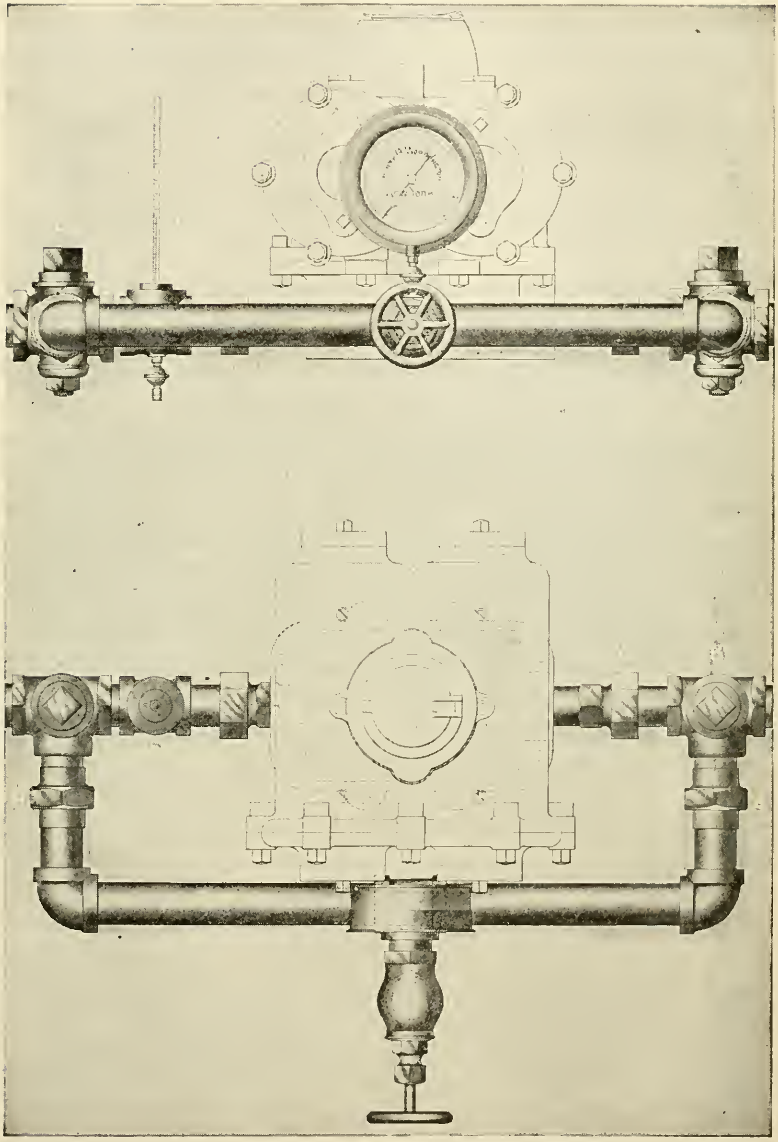
It must be absolutely reliable, doing its work with certainty, and without the necessity of such frequent care and examination as machines in general receive. In practice, it frequently happens that a meter is not looked at for many months. It will be seen, therefore, that a water meter, to be of any value at all, must combine durability, accuracy, reliability and low cost of repairs.

Following closely in the trend of improvements in machinery and the simplification of means for arriving at conclusions, the water meter became a close companion to the steam engine indicator. Its use, in connection with boiler plants, is practically the same as the use of the indicator in connection with steam engines; that is, for determining the actual cost of operating the plant. By the use of the indicator in connection with steam engines, the actual horse-power produced is determined. The test meter in connection with a boiler plant determines the actual cost of producing the steam to furnish the power.

Every engineer who has had control of a boiler plant has felt the necessity of having some simple device by which the amount of water fed to the boiler could be accurately determined. He is able by the use of the indicator to correct any irregularities in his engine or to determine the type of engine that would be the most economical to use. But without a machine for testing the various fuels that could be furnished him he would be unable to determine which of several is the most economical. In addition to this, with the use of a test meter the condition of his plant can be noted at any time without any delay or unnecessary preparation. The old method of testing boilers by weighing the water cannot be applied

for general use, owing to the fact that the expense of doing so would in the end amount to considerably more than the saving effected by the observations made. A careful manager naturally endeavors to make comparisons in the performances of his power plant and also of the evaporation of his boilers, from time to time, and, if a practical means of arriving at conclusions is not adopted, he finds himself frequently confused by conflicting results, arising from the supposition that his shop or factory consumes the same quantity of power at all times. Previous to the use of test meters by large manufacturing concerns, the cost of producing the steam necessary was based upon the duty the boilers performed at their test trial. It is found, however, in actual everyday service that the fuel consumption is much greater than the estimate, and that an enormous loss occurs somewhere. Managers were unable to determine the exact cause of this difference without the use of some simple device that would enable them to test their boilers at frequent intervals. A moment's attention to the Worthington meter I have before me may interest you. This meter is in every respect the same as the Worthington meter used by water works corporations, with the exception that the body of it is of composition instead of cast gray iron. The connections on the inlet and outlet sides of the meter are provided with three-way cocks. Extending from one to the other is a by-pass pipe, provided with a globe valve and a steam gauge. In the connection on the outlet side of the meter is placed a fitting for receiving a thermometer. There is no arrangement of feed water piping, pumps, heaters, filters, or other apparatus to which it cannot be applied, and with but a trifling outlay. It can be used without interfering with the operation and usual conditions of the plant for long or short periods, as may be desired, or it can be thrown out of commission entirely.

Owing to the errors introduced by dealing with very hot water under high pressure, the amount registered by the meter may not be exactly the same as that passing through the meter; but the difference between the two is always constant, and, when determined and applied to the counter-reading, the actual amount passing through the meter will be given. It must be borne in mind, however, that the error of the Worthington Test Meter is a very small percentage, and it is only in cases where great accuracy is desired that the counter-reading cannot be taken as final. The conditions being the same as those under which the test is to take place, the correction is readily found by setting the three-way cocks, as above described, so as to pass the water through the



Worthington Test Meter and Connections.

meter. The reading of the counter, together with the temperature of the water, furnishes (by consulting a table) the weight of the water passing through the meter in any given time. The three-way cock on discharge side of meter is then turned so as to cut off the boiler connections and allow the water to flow by the way of the angle valve placed in the loop around the meter and empty for precisely the same time in a cask or tank placed on a scale; the valve first having been closed until the pressure shown by the gauge is the same as when the water is passing through the meter against the boiler pressure. The relation between the weight of the metered amount and that found by actual measurement gives, in a percentage plus or minus, the correction to be applied to the counter-reading. In this way it is possible to test the meter as frequently as may be desired. Further, by properly setting the three-way cocks, and breaking the couplings, the meter may be removed without interrupting the flow of water to the boiler, or hindering in any way the operation of the plant.

In many of the plants which we have equipped with these meters the connection, as just described, has been left out. In such cases the meter is in constant service from the time the boiler plant is started until it is shut down for repairs. In many cases we have applied the meters in relay, thereby making the registrations of the meter almost positive. This is a much better plan for reasons which are apparent. By operating one of these meters for any given time and noting the readings on the log book in charge of the engineer, the duty performed by the boilers is recognized. The test meter not only determines which kind of coal produces the best result, but also restricts the waste of coal by the firemen. In several plants in which we have placed these meters great economy was effected. The economy was obtained by the careful use of coal, the regularity of attending to the boilers and in keeping the boilers thoroughly cleaned.

We have recently completed a test for one of the oil companies of this city who have a large number of our meters in use. The service required by these meters is rather a difficult one, owing to the fact that the maximum head is not over 8 feet, and the minimum about 8 inches. The maximum quantity is about one-twentieth the capacity of the meter, and the minimum about one-seventy-fifth. We took the oil tank and filled it full of water. This was carefully weighed, and the weight of the water at that time was noted. The water was then removed, and the tank was filled with oil and strained through the meter. It was again weighed and noted, and the error was one-sixth of one per cent.

Any meter which depends upon a rotary motion will show a percentage of error with different pressures. We took for our test one of the best rotary types in the market. We also took a disc meter, and placed them in series, allowing the same quantity of water to pass through the three different meters. The Worthington meter had been tested previously, and was found correct. It had been used under the same conditions as the others. The rotary meters showed very close in actual measurement when the flow of water was nearly up to the point at which it was rated, but when the quantity was lessened so that the discharge was not over one-seventieth the capacity, the difference amounted to 106%. This fact was taken advantage of by many concerns using rotary meters when they found the water would not register when it ran slowly. In St. Paul a peculiar case was noted. Several Chinese laundrymen found that by letting the water run slowly all night long they could fill their tubs without any expense. In the Worthington meter, if you will allow the water to run slowly, it will register just the same, and when it is reversed it will not work. The meter has grown from a plaything to a commercial piece of mechanism.

The Worthington meter has not changed in any of its principal features since it was first constructed. We have found by experimenting that with a certain class of meters we get better results than with other classes. We have been conservative in our ratings; they are the same as they were about forty-five years ago. The use of meters for boiler tests is coming rapidly into use. It is only the question of a few years when there will be no steam plant economy without some type of machine for registering the amount of water passing into the boiler to determine the evaporation.

DISCUSSION.

MR. E. P. ROBERTS.—I have been very much interested in Mr. Hoit's remarks, and think he has possibly put the case too mildly as to the value of the meter. He made one statement which I do not think he intended, and that is that you obtain the horse-power of the engine from the indicator cards, and that the principal value of the meter is in connection with the evaporation of the boiler. As a matter of fact, the obtaining any knowledge of the water from indicator cards is very questionable. The only way we can do it is to use the indicator cards to obtain the horse-power and measure the water before it goes into the boiler. The man who is using steam power studies all the items of economy

after the steam reaches the engine, but does not study so carefully up to that point. The water meter is necessary if he is going to obtain the exact cost of his steam, and the difference in the value of the fuel. One fuel at $1.25 may be more expensive than another at $1.50. He can learn this only by getting the evaporation of the boiler. Considering the very small cost of a meter, it seems remarkable that there is not one in almost every steam plant. We have had occasion to advise the use of a meter in a considerable number of plants, and in only one case have we found a man who was willing to spend the amount necessary. The water meter would receive greater favor if it were not for a suspicion as to its accuracy, but I think it is a recognized fact that where the Worthington meter has been used the results have been very satisfactory, even without calibration, and with calibration at time of test it is very convenient. I have just come back from two long boiler tests without the use of the meter, and it is neither pleasant nor easy to get the readings.

Mr. A. H. Porter.—I would like to inquire about the life of the meter, whether it has to have any special care, and whether any tests have been made of old meters to note the effect of wear upon them.

Mr. Hoit.—I can answer that question very easily, for the simple reason that I have in mind now two meters, one 21 years old and the other 19. The way it was discovered that this meter had been used 21 years was that the party who owned it received a bill from the Water Works Department for $2.50 for repairs, which he refused to pay. The early contract did not stipulate that he should keep the meter in repair, and they, in looking up the case, found that the meter was 21 years old. We tested the meter and found it 4 per cent. out. This meter was in Cincinnati, where the water is notoriously muddy.

The other meter is one which is now used in the Turkish baths in Cincinnati. The proprietor was taken ill and obliged to go West. He made readings before he left, and on his return he did so again, and found by the amount of water used that the receipts of his office should have been larger than were reported. Either the water or the money had been allowed to run to waste. This meter was 3 per cent. out after 19 years' service. The meters we have in this city have shown remarkable records, and the cost of repairs is very small.

Mr. C. O. Palmer.—About eight years ago, while I was in the employ of the Standard Oil Company, it was decided to test a certain rotary meter. For this purpose the meter was attached

to the oil supply pipe of the tank-wagon department. The oil flowed from a gauge tank in which it was accurately measured, affording a very good test of a meter, so that I looked for the result with interest. I did not take the readings myself, but those in charge told me that the meter was away off. It was absolutely useless as a check upon the man who had charge of the gauge tank.

The same company had used several piston meters for a number of years to measure the water supplied from its own water works to different departments of the plant. The water was taken from the river and contained more or less mud and sand. On one occasion I was told to test a couple of these meters which had been already connected with a gauge tank for that purpose. The first of these, a Worthington meter, No. 36,071, registered 19.96 per cent. of the amount passing through it as shown by the gauge tank, the flow being at the rate of 7.46 cubic feet per minute.

At another test, the same meter, as I remember, was placed on the outlet pipe, together with a 2-inch Worthington meter, No. 31,451, so that the discharge passed through both. With a flow of 3.3 cubic feet per minute, as determined by the tank measure, the result was as follows:

Tank measure......................	485.84	cubic	feet.
2-inch meter......................	514.	"	"
4-inch meter......................	90.	"	"

This result goes to show that the readings of an old meter are not to be taken without question, and that when a leaky meter is run at a rate much below its normal capacity, as often happens, even a piston meter may record but a small fraction of the water passing through it, especially when it has not been fitted and calibrated for the place in which it is intended to run.

Mr. Hoit.—In testing or calibrating old meters, every condition must be considered, i.e., the pressure under which the meter is operated, the character of the water passing through it, the maximum quantity to be delivered at any one time, and the average quantity to be delivered at all times. In testing the 2-inch and 4-inch meters referred to, probably the same connections were used for both. This would be an incorrect method, and would in itself result in error in one or the other of the meters, even though they were absolutely correct under the conditions for which they were sold.

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ROMAN CONSTRUCTION.

BY G. W. PERCY, MEMBER OF THE TECHNICAL SOCIETY OF THE PACIFIC COAST.

[Read before the Society, September 2, 1898.*]

MANY books have been written and innumerable plates have been published describing and illustrating the wonderful architectural and engineering works of the ancient Romans.

The history of Roman art is well known. Their architectual forms are recognized by every intelligent observer, and the minute details of their style and orders have been familiar to architectural students for the last three centuries.

There is hardly a known fragment of Roman architecture in existence that has not been carefully measured, drawn and published to the world during the present century.

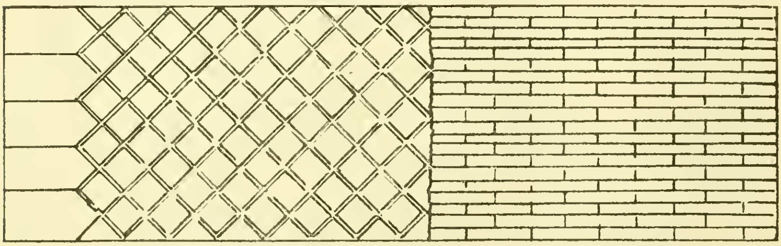
And yet, with all this widely published knowledge of Roman art and architectural forms, there has been very little attention given in modern times to Roman methods of construction, and very few, even among architects and engineers, are aware of the fact that the ancient Romans, especially of the best days of the Roman Empire, devised and perfected a method of construction perfectly adapted to their gigantic works and possible of execution with unskilled labor and with the cheapest and most common materials.

Nearly all writers who have attempted to describe Roman buildings and the materials with which they were built, have classed them as of cut stone, or of brick faced with marble.

*Manuscript received October 4, 1898.—Secretary, Ass'n of Eng. Socs.

Others who have investigated a little beneath the surface have described some Roman walls as a combination of brick and rubble stone work, with occasional bond courses extending entirely through the walls, consisting of large flat tiles.

Vitruvius, the earliest architectural writer whose works have come down to us, declares, in the introduction to his ten books, that he has developed all the principles of the art of architecture. Yet, while he describes very minutely all classes of building material and their proper use, he gives no hint of what the ruins show to be the true Roman construction of walls and arches, which method became general about his time. Whatever Pliny and



Elevation.

a b

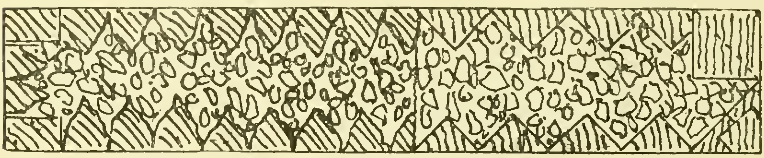


Fig. 1.
Plan of Wall.

other ancient writers have recorded of Roman construction they appear to have copied from Vitruvius.

During a visit to Rome in 1882 the writer was much interested in examining the stupendous ruins of buildings, aqueducts, etc., and noticed what to him was a strange discovery,—that the walls and arches of such buildings as the Baths of Diocletian and Caracalla, the Basilica of Constantine and many other ruins were not of bricks, as he had been led to suppose, but of great masses of concrete, faced with bricks. In many places where the brick facing had been stripped off the concrete mass presented a rough face with numerous indentations, as if bricks had been laid diagonally with the corners penetrating the concrete. This was a new revelation to him, but he had neither the means nor time to

investigate further than what was on the surface and exposed to view. The discovery, however, added new zest and desire to read whatever he found about Roman construction. When in 1885 a book was published by J. H. Middleton, an English architect, entitled, "Ancient Rome in 1885," giving the result of extensive investigations, and revealing the fact that all so-called brick walls in Rome of ancient construction were of concrete, faced on both sides with triangular bricks. Middleton declares that there are no walls of ancient Rome built throughout of brick, and that walls only seven inches thick are faced with very small triangular bricks and filled with concrete. See Fig. 1, *a*.

This made clear the cause of the indentations which had so puzzled the writer, and showed a logical intent on the part of the builders.

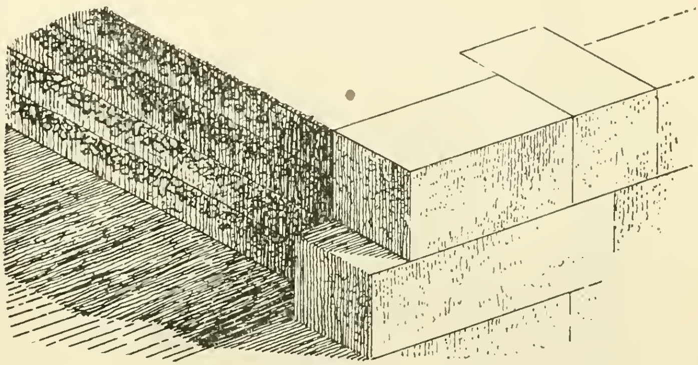


FIG. 2.

In a more recent work, "The Art of Building Among the Romans," written by Auguste Choisy, a French architect, a translation of which by Arthur J. Dillon has been published in the *Brick Builder* during the years 1892-95, makes clear to English readers for the first time the system practiced by the ancient Romans. To this work the writer is indebted for the graphic illustrations of this paper, and to some extent the descriptions.

The etchings by Piranasi show how some of the ruins appeared one hundred and fifty years ago, while the photographs show the appearance of other ruins at the present time.

It will be seen by examining these etchings and photographs* that in many places what appear on the surface to be brick arches over openings and relieving arches through the body of brick walls have fallen out or have been destroyed, and the remaining mass shows that the arches, like the plain facings, were but skin deep.

*Etchings and photographs omitted in publication.

A close examination of the interior surfaces of domes and the soffits of large arches often reveals a framework of thin brick arches forming a skeleton of bricks imbedded in the mass of concrete or rubble work.

Auguste Choisy made a thorough examination of these and other peculiarities and arrived at the following conclusion: That Roman masonry generally consisted of an agglomeration of small stones and mortar, with facings of cut stones or triangular bricks, except for foundations and other works below the level of the ground where the earth, and sometimes timbers, served to confine the mixture. This concrete or fine rubble work is of two kinds—that which was placed in trenches or behind solid stone revetments was of rammed masonry, formed by spreading a layer of mortar

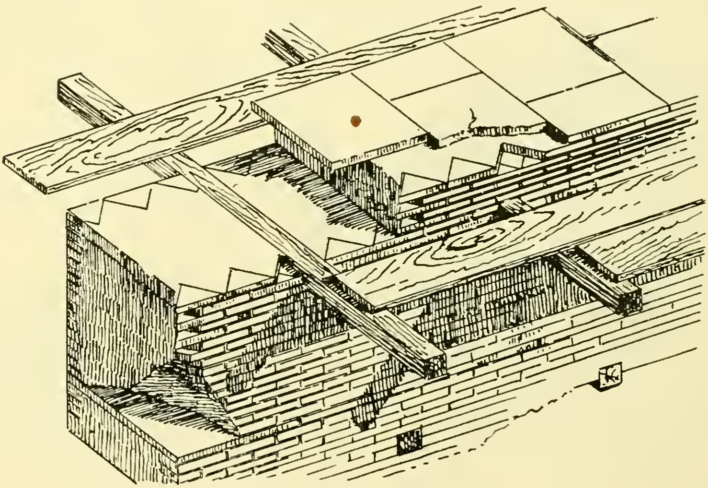


Fig. 3.

four or five inches thick, and then spreading over it a layer of equal or greater thickness of small broken stone and ramming the stone down into the bed of mortar, thus forcing the mortar into all the interstices and bringing some of it to the surface. Then a thin layer of very fine fragments and dust resulting from the facing of the cut stone was spread, which prevented the mortar from adhering to the feet or tools of the workmen, and the whole was again rammed solid, when the operation was repeated with a fresh layer of mortar, rock and dust, thus making a very compact mass in well-defined layers eight or nine inches in thickness. Fig. 2.

This method seems to have been employed in all cases where heavy cut stone facings or earth pressure gave sufficient resistance to the outward thrust caused by the ramming.

The other method of building with conglomerate masonry and where ramming is not employed is by far the most common, and is always found where brick or small stones are used for facings. These facings were doubtless laid one or two courses at a time and for the same purpose as the larger stones, to confine the fresh rubble and to form straight and true faces to the walls, which were afterwards veneered with marble or covered with stucco.

Some writers have assumed that the interior filling was mixed as concrete is now, and poured while in a semi-liquid condition between the facings, but Choisy demonstrates quite clearly that such could not be the method employed, but that layers of lime mortar, as before only from one to one and a half inches in thickness, were

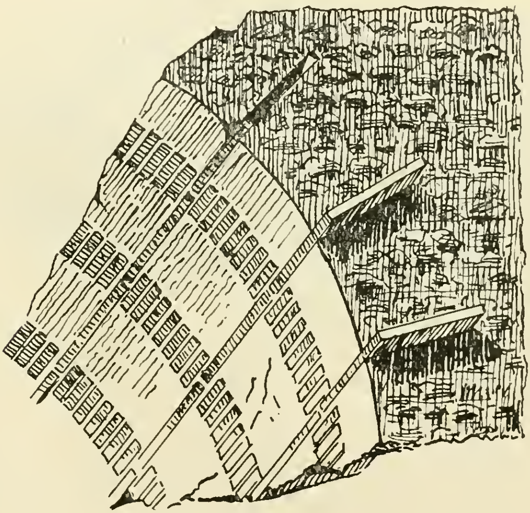


FIG. 4.

spread between the facings, and then the broken fragments were placed by hand and pressed down into the mortar. This is shown by the fact that the stones are always placed on their natural bed, and where pieces of pottery are used they are always placed with their faces following the horizontal plane, and again where fragments two or three inches thick are used, as sometimes occurs, it is frequently found that the layer of mortar spread over the top does not go down between these large fragments to meet the lower bed of mortar, thus leaving gaps in the vertical joints which would not occur in a mixed semi-liquid concrete, and which are seldom if ever found in the rammed work.

The triangular bricks used for facing such walls and confining the rubble were from one foot to twenty inches long, and from one

to one and one-half inches in thickness, and laid generally with very thick joints, often one inch in thickness, of lime mortar, generally with pozzuolana used in place of sand.

Often, in the earlier works, the faces of the walls were of small stones about six inches square on the face, and from ten to twelve inches long, and laid with diagonal joints forming what Vitruvius calls "reticulatum opus." Fig. 1, *b*.

In all these cases we see that the principal object of the brick and small stone facings was to confine the rubble work and protect it during the process of setting and hardening, while at the same time it was thoroughly incorporated in the mass of the wall.

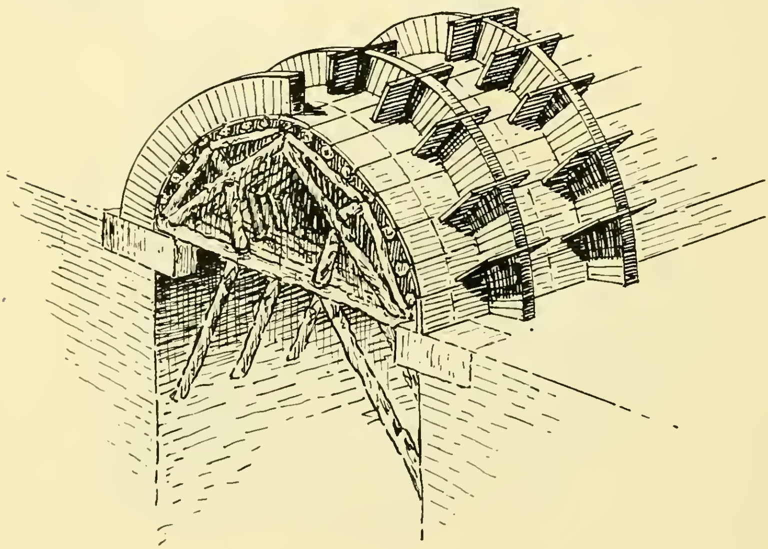


Fig. 5.

In this manner all expense and wastefulness of temporary curbing was avoided, and substantial walls were erected, largely with unskilled labor and with the commonest materials.

In building walls of this character it is evident that some method of bonding the two opposite faces at intervals should be employed, and this (Fig. 3) the Romans effected in two different ways. Often both methods were employed in the same wall.

In the first method sticks of roughly hewn wood were placed, extending entirely through the wall. Vitruvius refers to this method of bonding, and says in Chapter 5, Book 1: "The walls ought to be tied from front to rear with many pieces of charred olive wood, by which means the two faces thus connected will endure for ages. The advantage of the use of olive is that it is

effected neither by weather, by rot nor by age. Buried in the earth or immersed in water, it lasts unimpaired, and for this reason not only walls of cities, but foundations and such walls as are of extraordinary thickness, tied together therewith, are exceedingly lasting."

It is quite probable that these bonding sticks were allowed to project on both sides of the walls to support scaffolding for the workmen and materials, and, when the walls were finished, they were cut off flush with the face.

The wood has rotted out from all these Roman walls, but the imprint in the masonry gives proof beyond question of their former existence.

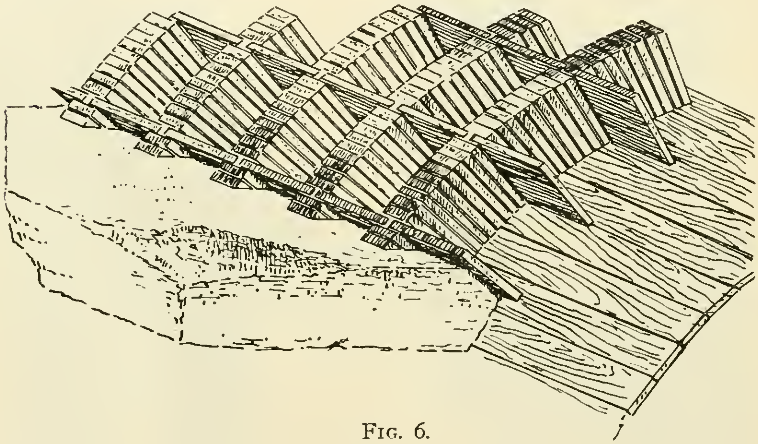


FIG. 6.

The second method of bonding, which has proved more durable than even charred olive wood, is also shown in Fig. 3. It consists of flat tiles of burnt clay, or large bricks, about two feet square, and from one and one-half to two inches thick. These are often used in single layers from four to eight feet apart, and sometimes with two or three courses together. This method of bonding is a strongly marked peculiarity of Roman walls wherever found in Europe.

But it is in the construction of vaults and arches that we find the ingenious method of the Romans carried to its greatest perfection, and the greatest saving of skilled labor and expensive materials.

While arches of cut stone with radiating joints were used by the Romans in their bridges, triumphal arches, city gates and some other monumental structures, rubble vaults were far more common and were built on a most stupendous scale.

These vaults, formed of small materials, were of infinite variety, and are found covering rectangular and polygonal spaces, rotundas and exedras; for, being, as it were, moulded, they could be adapted to the most varying forms, and could be made to meet all of the numerous requirements of planning.

The Romans may or may not have been the inventors of rubble vaults; that is to say, of vaults of small stones bound together with mortar, but it is certain that before them no one thought of constructing vaults of large span of such materials. With them it seems to have been developed during the latter days of the republic and the early days of the empire, or about the beginning of the Christian era.

The system developed rapidly, and the Pantheon is preserved to us, a masterpiece of the art and one of its earliest examples.

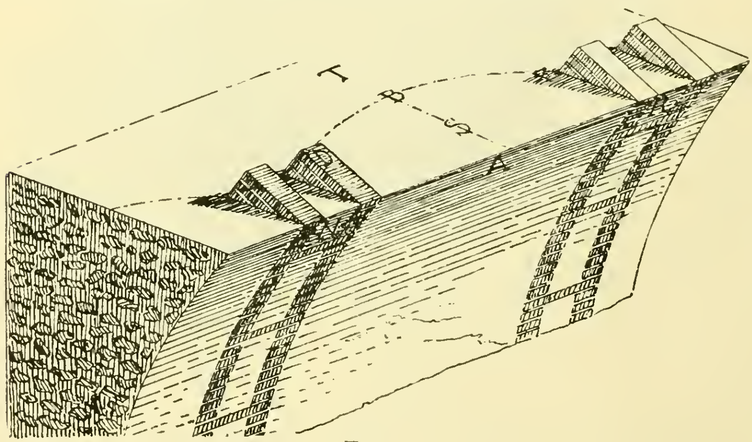


FIG. 7.

If one inspects an edifice vaulted with rubble, as for example the great Baths of Caracalla, he will perceive on the face an arch of brick with radiating joints, and behind these face arches a rough masonry similar to the interior of the walls we have described, but if one examines these masses of masonry more closely he discovers courses of an entirely separate construction imbedded in them, real ribs, sometimes entire networks of bricks forming skeletons in the body of the rubble.

This skeleton must not be considered as a series of relieving arches built at the same time as the rubble and intended to strengthen it. These arches of bricks in the Roman vaults were built first, with radiating joints and bonded to each other and to the face arches at intervals with large tiles, thus forming a complete framework which could be built on a light and inexpensive

centering, and which in turn supported the body of the arch as it was carried up with horizontal courses exactly as described for the walls.

Fig. 4 shows the appearance of such a vault with the facing bricks removed.

It is evident that the construction of wooden centering, of sufficient strength to carry such massive arches in a perfectly rigid

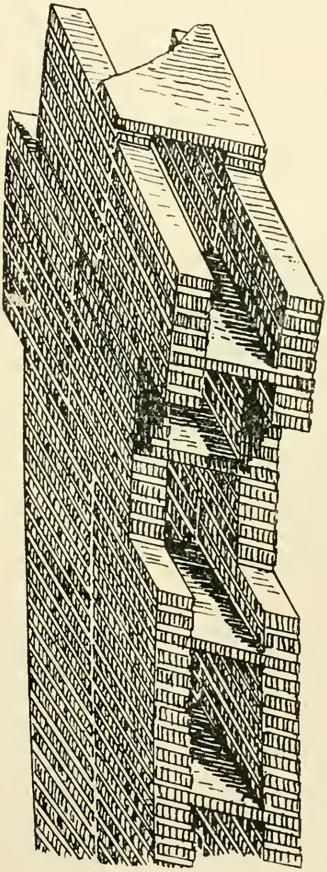


Fig. 8.

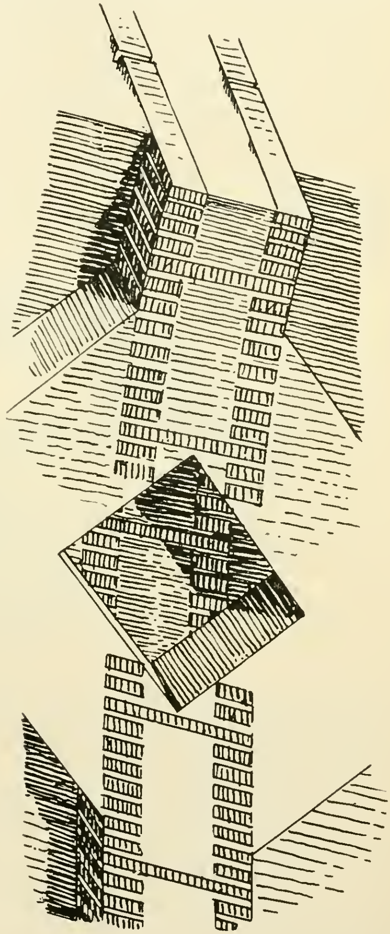


Fig. 9.

state while being built, would be a work of great expense and delay, requiring vast quantities of timber, considerable skilled labor and a great deal of time, all of which the Roman builders sought to avoid using unnecessarily.

Some centering indeed was necessary to support the light ribs of bricks on which to form the rubble. Such centering was con-

structed in as light and crude a manner as possible, generally of round or rough-hewn logs, supported on corbels of brick or stone projecting from the wall, roughly formed to the curve of the arch with bricks and earth, and, where necessary, further supported by vertical props. Fig. 5.

This rough centering was often paved with a layer of large, thin, burnt tiles, laid with open joints which would receive the rubble masonry and adhere firmly to it, thus forming the permanent soffit of the arch when the centering was removed. At other times it was covered roughly with boards which have left their imprint in the masonry of the arches.

The ribs or armatures of the arch were then turned rapidly and roughly, as is shown by their irregularity in many of the ruins. They were usually constructed with bricks about 6 x 24 inches, slightly wedged and laid in strong lime mortar. At intervals of

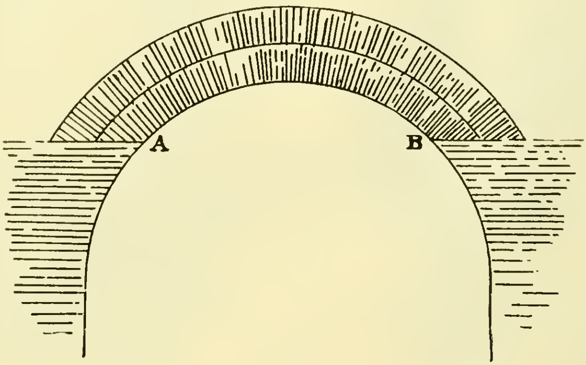


FIG. 10.

two feet or more large tiles or bricks about 24 x 24 inches were built in, forming wings, as shown in Fig. 5, or bonding the ribs together, as shown in Fig. 6.

At other times the ribs are built in pairs, with a space of eight or ten feet between them, as is shown in Fig. 7.

In still other cases, where very large arches were to be turned, as in the Basilica of Constantine, where they are about seventy feet span, these ribs were made double in height, as is shown in Figs. 8 and 9.

These light ribs of brick, once completed and bonded together over the rude centering, were of sufficient strength and rigidity to support the rubble work as it progressed, and were swallowed up by it, becoming thoroughly incorporated as a permanent part of the construction.

It is evident also that the work need suffer no delay while the

centering and ribs were being constructed; for, as shown in Fig. 10, the overhang of the walls was slight for about one-third of the height of the arch, and up to that height would cause little or no pressure on the ribs or centering, but it was necessary that the ribs should be completed before the work was carried higher.

Many barrel vaults of smaller dimensions were turned on armatures of two courses of bricks or tiles laid flatwise, the lower course laid continuous, of large bricks, and the second of smaller bricks covering the joints and forming blocks or bands as represented by Figs. 11, 12 and 13, the top course being laid in plaster or quick-setting mortar.

Of this type are many of the vaultings in the Baths of Caracalla.

When it came to groined vaultings, the Romans practiced the

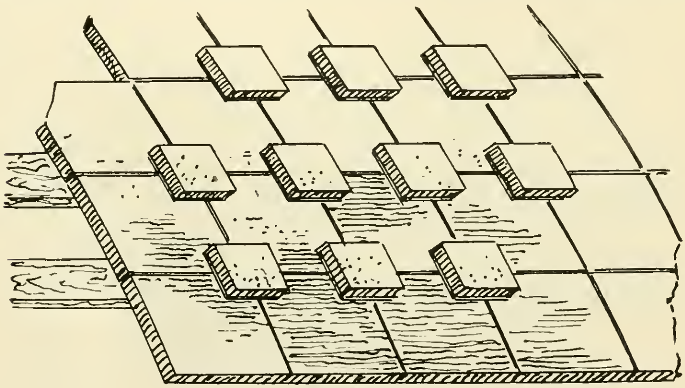


FIG. 11.

same economy in the employment of skilled labor and costly materials. It may be said in general that where practicable the Romans avoided the intersection of barrel vaults, but, where the requirements of the plan demanded it, they sought to make both barrel vaults of the same width, and where that was not practicable they usually stilted the narrower one so as to bring the top level with the large arch.

The centering and ribs were constructed in general as has been described for barrel vaults, but with the precaution of always having rigid ribs to form the groins (Figs. 14 and 15), or, if flat tiles were used, an extra course was laid long the line of the groin. (Fig. 16.)

In building circular domes the same elaborate system of ribs and skeleton armature was carried out.

The dome of the Pantheon, the largest, oldest and most per-

fect dome in masonry, and which some writers have described as of solid brickwork, others of solid concrete, proves by investigation to be of the fine rubble work we have described, with an elaborate system of ribs and arches incorporated.

Piranesi, the famous etcher of the last century, who devoted his life to producing in this manner the most perfect representations of the ruins and architectural features of Rome, made extensive investigations into the structure of the dome of the Pantheon while repairs were being made, and produced an etching of which Fig. 17 is a diagram.

The methods here presented are not the only ones employed by the Roman builders in constructing their vaults and arches. Many special devices were adopted as the difficulties and necessities presented themselves, and many combinations of different

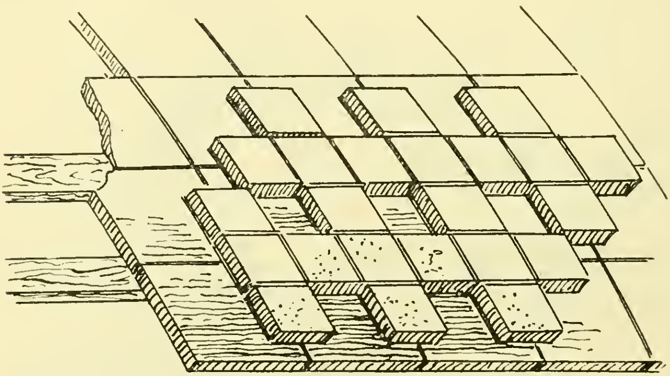


FIG. 12.

methods were employed, the object appearing to be always to prevent waste of valuable materials and skilled labor in erecting temporary and auxiliary works.

A study of these ingenious contrivances not only gives us an insight into the conditions under which Roman builders labored, but must increase our respect and admiration for their engineering and constructional ability.

Study of the ruins of Roman work indicates that the methods here described arrived at their greatest perfection during the first two centuries of the Christian Era, gradually falling into disuse and disappearing in the fifth century, after which few buildings of magnitude were erected in Rome until the days of the Renaissance, when the old Roman methods had been long forgotten, only to be investigated and comprehended in these latter days of the nineteenth century.

DISCUSSION.

PRESIDENT MOLERA.—When lime mortar is buried for a year or two in pits, it is supposed to absorb carbonic acid from the air, thus tending to return to its previous state of lime rock. The reaction takes place in the mortar itself. I suppose that in these large pits the covering was not such that it was hermetically sealed against the air, and that the air inserted itself into the mass. An analysis of the mortar in the ancient work of the Romans shows there is a great deal of carbonic acid in it.

Q.—Mr. Percy, as you have described the mortar with stones put in it, is it not something like our concrete? Do you know whether our modern concrete was known to the ancient Romans, and used by them?

MR. PERCY.—I think not. I think the method described by the writer I have quoted from so liberally must have been the one

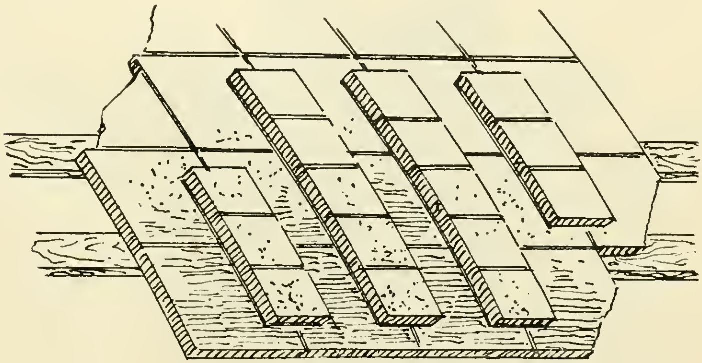


FIG. 13.

employed. If the materials were mixed together and put in as we put in concrete now, there certainly would not be any well-defined layers. He says that in large work it is in layers eight, nine or ten inches thick. Evidently the mortar was first put in and the stone was then rammed down into it, bringing the mortar to the top. The most common class of work is with brick facing. If the mortar had been poured in in a semi-liquid state the layers would not be so well defined. It is self-evident that the small stones or fragments of pottery were put in by hand, for they are always placed in a horizontal position. If they had been poured in they would be in all positions. Then, again, in these layers there is always mortar at the bottom, growing less as it comes upward in the course. The whole thing is logical when we consider that, in building a wall, common square bricks would not make a very good bond, but in such masonry the rubble filling with triangular

brick facings makes an excellent bond. There could not be a better bond devised than the triangular brick. This also would be an economical way of building walls, for it could be done with unskilled labor. It is very evident that the Romans had abundance of labor. They had great numbers of captives, and even their soldiers were put to work on these buildings and great structures. All sorts of labor were employed. It is apparent that this method was adopted so that a great amount of unskilled labor could be used in doing the greater part of the work, using skilled labor only for the finishing touches and the ornamentation. The ornamentation is of a Greek type, although the construction is Roman.

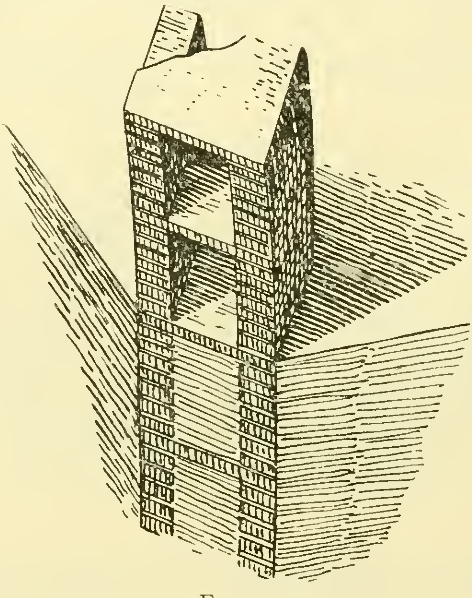


FIG. 14.

They brought Greek architects and Greek workmen to Rome to do this class of work. With this outside finish and ornamentation stripped off we now see the real Roman work and construction.

Q.—Do you understand this construction would apply to such buildings as the Colosseum and the great aqueduct?

MR. PERCY.—Yes, the Colosseum is of this method of construction, and of cut stone. The outer wall, and the second series of arches, and a good part of the third series are of massive cut stone, but the interior parts are almost entirely of bricks and of small fragments of stone and mortar. Perhaps it would be proper to call it rubble work; evidently the mortar and stone were put in by hand. It looks something like concrete, and it may be properly

called a fine rubble. The cut stone is travertine. Some of the piers and arches of the aqueducts are of cut stone. The piers and arches of the largest aqueduct in Nero's time, for instance, were of brick and rubble. A very interesting thing about it is that some of the arches proved too weak to carry the weight, and they have been reinforced by other arches built inside of them, and the piers have been thickened. The inner arches were built entirely of brick. A few inches were left between the crown of the new arch and the under surface of the old arch, and then on one side of the wall this place was bricked up, and this mixture of stone and bricks and mortar was rammed in from the outside into all the space between the two arches, thereby strengthening the original arches.

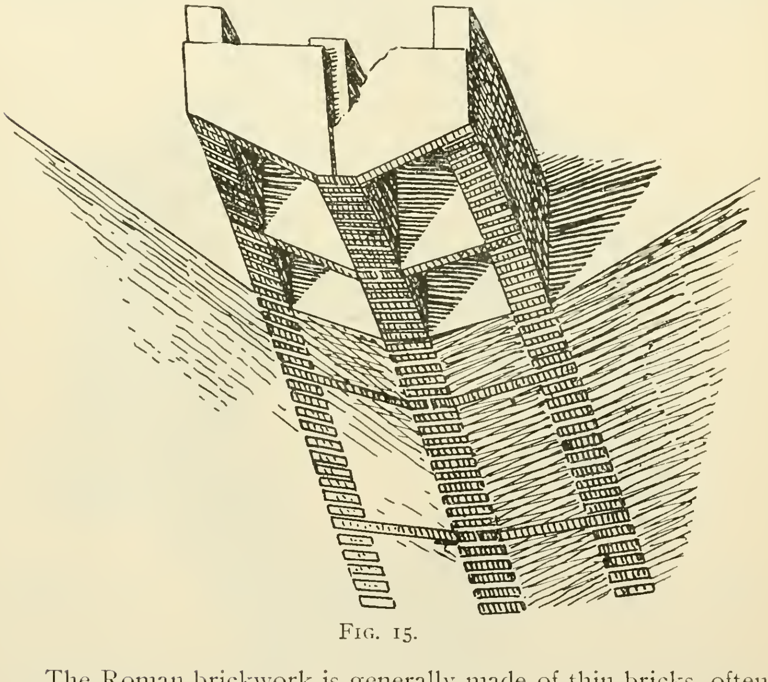


FIG. 15.

The Roman brickwork is generally made of thin bricks, often not over an inch in thickness. It is a very common thing to find the joints as thick as the bricks are. The mortar between the bricks has coarse sand in it. This is not intended to be seen, but to be covered up by the hydraulic cement I have spoken of, which also keeps the water from penetrating.

All the great arches, including the triumphal arches, were built of cut stone, and not of concrete and brick; also most of their gateways. The oldest Roman work is entirely of cut stone, and no mortar was used. The stones were fitted very closely to-

gether. About the time of Christ, roughly speaking, this method of using triangular bricks became the common method, and is particularly shown in those monuments built in the first, second, or third centuries of the Christian era.

The Romans at first used a volcanic tufa quarried on the site of Rome. It is not very enduring, and not very hard. All walls that were exposed were covered with stucco, both for appearance, I suppose, and preservation. As the Romans became more powerful, they wanted to build more enduring buildings, and they went to the foothills and mountains beyond, twenty-five or thirty miles, where there are excellent quarries of stone. You have a sample of this stone here in Golden Gate Park in the Keyes monument. That is Roman travertine. It is a very hard, enduring lime-

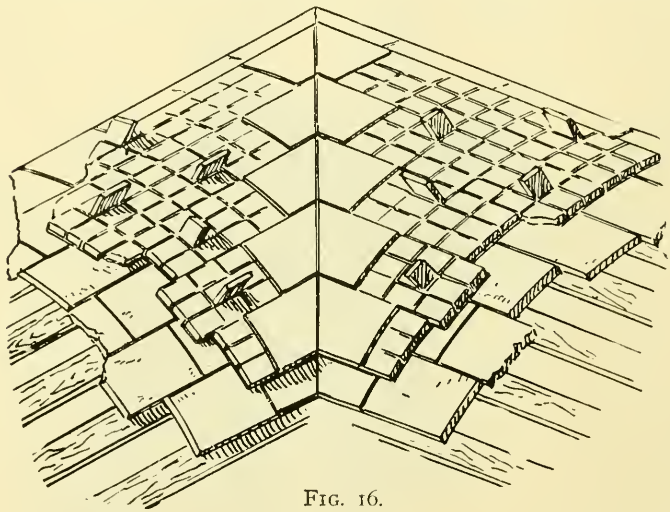


Fig. 16.

stone. The Colosseum and St. Peter's are built of that material. It was used very generally for building purposes. Temple building, up to the time of Christ, or soon after—such temples as the Temple of Saturn—are all built of white marble. In the first three centuries of the Christian era the Romans were not satisfied to use white marble, and they brought the richest and finest varieties of marble that could be found anywhere in Africa or Asia. The most of this marble has now disappeared, but fragments are still found.

The stone dug out of the catacombs was a soft tufa. I do not think any of the cut stone came from there, or that it would be practicable to quarry stone out of such narrow passages. The Romans probably made use of the tufa taken out of the catacombs, but they could not have quarried building blocks of stone out of

passages four and eight feet high and extending for miles in all directions. No sane man would take that method of quarrying stone, and certainly the Romans were logical people, as we have seen in the construction of their buildings. The catacombs, I believe, were made solely for burial places. The stone taken out is inferior material, at best, for building purposes. We find in this concrete or rubble work something of a guide to the age in which

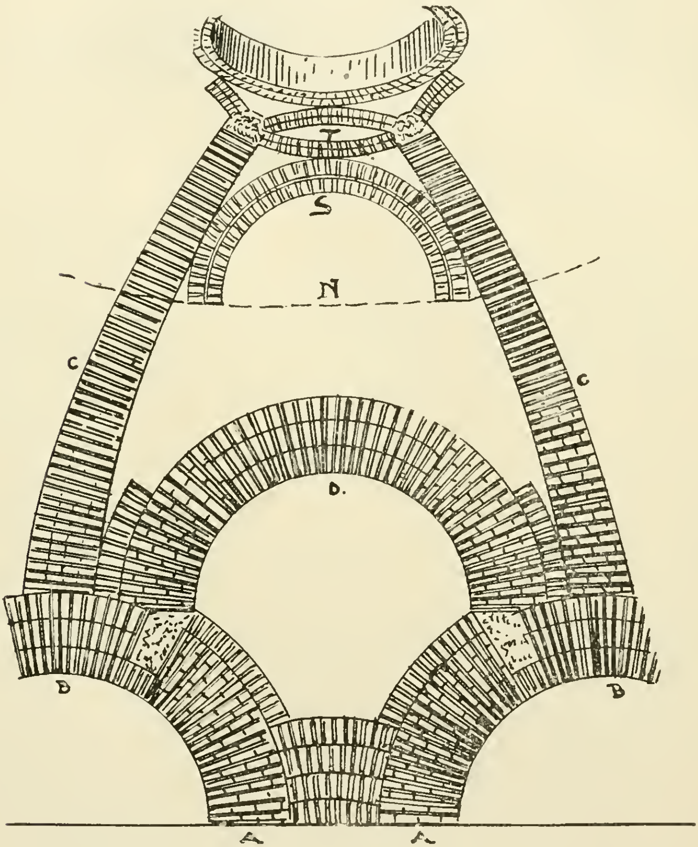


FIG. 17.

it was used. In the earliest work the tufa is the most common material in the concrete or rubble work. In a later period we find the travertine, and, still later, fragments of all kinds of marble, of chippings of marble, and of basalt and other stone, showing that the chippings from the stone they used for facing their temples all went into their concrete or rubble work, and nothing was lost or wasted.

I do not know of any granite near Rome, and yet we find granite used there in modern times. The church of St. Paul was burned in 1828 and has been rebuilt. There are a great number of very large columns, and they are of polished gray granite. Everything else is marble, but the columns are of granite. Where the granite came from I do not know. We find here the architectural works of the Greeks. They not only rubbed the joints of stone together to a perfect joint, but even polished the joints. I do not believe there ever was such a waste of labor anywhere in the world as that. Unless I saw it I could hardly believe that such things were done.

IMPROVEMENT OF THE MISSISSIPPI RIVER DELTA.

The Louisiana Engineering Society is not responsible, as a body, for the facts and opinions advanced in any of its papers.

By Thos. L. Raymond, Member of the Louisiana Engineering Society.

[Read before the Society, March 14, 1898.*]

It is scarcely necessary to dwell upon the importance of this question at this time, for that is self evident, after the recent agitation of the subject before Congress by the public-spirited citizens not only of our own section, but of the whole valley of this great river, and in view of the expiration, in two or three years, of the contract for maintenance of the channel through South Pass by the Eads Estate.

A brief review of the methods which have been tried or suggested in the past for the improvement of the entrance to the river will be useful in this discussion, and these will be the better understood if we recall the conditions which have prevailed at and near the mouth of the river, as determined by the unmodified work of nature.

At a distance of twenty-five miles from the Gulf, measured along the channel, the river is 2700 feet wide, with a maximum depth of ninety-four feet. Just below this point the west bank was breached by a crevasse many years ago, and an outlet formed called "The Jump." It is twelve miles long, very narrow, only twelve to fourteen feet deep, and débouches into four feet depth in the Gulf, at a distance of seven miles from thirty feet depth. Another opening in the east bank is met seven miles below the Jump, and is known as Cubit's Gap. This may be considered as one of the mouths of the river, and it empties into the Gulf through a channel four to seven feet deep at a distance of nine miles from thirty feet depth.

Opposite Cubit's Gap, the width of the river has increased to 4100 feet, and its depth decreased to fifty feet; and this widening and shoaling progresses until the "Head of the Passes" is reached, where the width of the river is 6900 feet, and the depth thirty-three feet, in a channel entering Pass a l'Outre.

The river here divides into three main streams, viz: Pass a l'Outre, flowing about east; South Pass, flowing southeast, and Southwest Pass, named from its course.

*Manuscript received October 10, 1898.—Secretary, Ass'n of Eng. Socs.

Pass a l'Outre, before the work on South Pass was begun, was fourteen miles long and carried from the river forty-six per cent. of the whole volume of the river reaching the Head of the Passes. For the upper third of its length it afforded to commerce a channel 1500 feet broad and a least depth of fifty feet, but in its further progress to the sea this great volume was and is depleted by a number of outlets, two of which are of very considerable capacity, leaving in the main channel a volume of water which requires a width of 1100 feet and a depth of scarcely forty feet to carry it to the sea, while the rate of the current is so much reduced by this repeated lowering of the head or flattening of the slope that the depth over the bar was only about nine feet. During the last four years this deterioration has doubtless been augmented by the formation and enlargement of another great outlet known as Pass a l'Outre Crevasse, only two miles below the Head of the Passes.

South Pass, before Mr. Eads began the work of its improvement, was ten miles long, and carried only eleven per cent. of the total volume passing through the three mouths. The entrance to it from the river was divided into two channels by an island, while the main banks, widening out to a funnel shape to enclose it, had the effect of gorging the water entering the pass at its narrow throat, reducing the slope and consequently the current through the wider part above, and thus forming a bar across the entrance with only fifteen feet of water over it. For a short distance down in the pass, with a width of some six hundred and fifty feet, a depth of thirty-eight feet and over was maintained; but, below this stretch, the width, enlarging to 1100 feet to enclose another island, reduced the depth to thirty feet. Five miles below the head an outlet through the west bank drew off to the sea as much as twenty-three per cent. of the total volume entering the pass, with the inevitable diminution of depth to as much as ten feet less than what was found above. A short distance above its mouth a small outlet still further reduced its current and capacity, and finally, at a distance of one and a half miles from shore, the crest of the bar was found with a depth of only eight feet over it. Through a great part of its length the width of this pass is only six hundred feet.

Southwest Pass carried forty-three per cent. of the water in the river below Cubit's Gap. Its least width is about 1200 feet, and its channel depth varies from fifty to seventy-eight feet through twelve of its fourteen miles of length, and the shoaler two miles are at its mouth, where the banks widen out to the open sea. While this pass was being used constantly as the entrance to the

river the depth of the channel over the bar was usually about fifteen feet, but it has since shoaled to about nine feet.

Several methods have been suggested by engineers of repute for obtaining a deeper channel into the river from the Gulf than nature has provided. The first and simplest was by dredging through the bars by harrows, but this was soon abandoned, when the difficulties of working in the open sea were encountered, and when the action of the cross currents in refilling the narrow cut were learned by experience.

The second plan attempted to protect the channel by a sheet pile jetty on the east side and excavate under its protection. This plan succeeded in opening through Southwest Pass bar a channel eighteen feet deep, but the protecting wall was soon destroyed by storms, and the contractors failed to obtain the twenty feet guaranteed by them.

The third method was adopted by the United States Government about 1870, and consisted in stirring up the material composing the bar with large propellers, lowered to the proper depth, deflecting the surcharged water to the surface, and thus utilizing the strong current to transport the suspended material to deeper water. Two large and expensive vessels, built for this purpose, succeeded in obtaining eighteen feet depth by this method across Southwest Pass bar for a part of the time during three years, but the results were extremely unsatisfactory, as the channel was quickly obliterated by storms and was very narrow, and, as only the finer material was removed, the bottom became dangerously hard from the greater proportion of sand remaining.

The fourth method was that of flanking the mouths of the river by a canal with locks, connecting the deep water of the river with that of the Gulf at a point some thirty-three miles from the mouth. The object to be attained by this plan was the prevention of the bar formation by avoiding the constant flow of sediment-charged water through the entrance to the Gulf. This plan never reached a stage beyond that of surveys and estimates. It was the first suggested in 1832 by Ch. State Engineer Buisson, and was revived in 1870. The discussion of its merits, in comparison with jetties, was long and bitter, but after volumes had been written in defense of both projects, the jetty plan was adopted tentatively by the general government, on the guarantee of a private individual to make a success in South Pass.

Whatever may or could have been claimed for the canal in the early seventies was based on obtaining a navigable depth of twenty-five feet, considered at that time ample for the commerce of the

world, but, as the vessels of the present day require at least a thirty-foot depth, with the prospect of this being exceeded in the future, a glance at the chart will show that no safe navigation for such draft can be found through Breton Sound, which it was proposed to connect with the river by canal. Looking at this in the light of what has been accomplished by the jetty plan, it seems strange that a splendid natural channel of ample width and depth, with only four miles of shoal water dividing it from the deep basin of the Gulf, should be abandoned for ten miles of artificial waterway, limited in width and depth by considerations of cost, subject to the delays and uncertainties of lockage and finally reaching an arm of the sea difficult of safe navigation. For a vessel of thirty feet draft Breton Sound is not possible of safe navigation, and a locked canal between it and the river is not practicable at any reasonable cost.

The last and only successful plan was and is the jettying of one of the passes. This method of bar improvement has since the construction of those at South Pass, been applied, with numerous modifications and varying degrees of success, to many other harbor entrances in the United States. It aims to do suddenly, in the process of bank building, what the slow processes of nature accomplished only in centuries. Seaward of all harbor entrances the conflict of the littoral with the outflowing currents checks the movement of the sediment or sand carried by either, causes deposit and forms bars, the depth over which varies with the many varying conditions.

The Mississippi below St. Louis is a marvelous type of a sediment-bearing river, and it has been estimated that it annually transports to the Gulf a volume of solid material represented by a mass one mile square and two hundred and sixty feet high. The shoals which blocked the entrance to all of its "passes" were built up chiefly by the material carried out of the river, which is dropped by the current progressively as its rate is diminished with the widening of the distance between the banks, and more rapidly after the sea has opened its broad expanse to the flow. As is to be expected, the greatest amount of deposit occurs on each side of the thread of the current, though the western side of all the entrances built out the more rapidly, due perhaps to the sea currents being controlled largely by the prevailing winds, and also to the rotation of the earth from west to east, causing the deposit of a greater proportion of the drift and suspended material on the western side. The momentum of the current, the shoals on either side beyond the mouth and the head retained as far as the visible

banks extend, produce a current which is able to support and carry material some distance into the Gulf, and these factors regulate the distance from Land's End to the crest of the bar. The distance from thirty feet inside to thirty feet outside is, for Pass a l'Outre, three and three-quarter miles, for Southwest Pass four and one-half miles, and for South Pass, before its improvement, two and one-quarter miles.

As the process of bank extension progresses from year to year the rate of flow is maintained for a greater distance into the Gulf, carrying the material further and producing a yearly bar advance, which has been the cause of great doubt in the minds of many unprejudiced students of the problem as to the economic success of the jetty system at the mouth of the Mississippi. This bar advance has been estimated, by comparison of surveys extending over many years, at three hundred feet for Pass a l'Outre, one hundred feet for South Pass and two hundred and sixty feet for Southwest Pass, and the fear has been entertained that, with jetties completed, this rate might be greatly augmented, as much as four-fold having been claimed by some. This being, to my mind, the chief argument of value against the improvement by jetties, I beg leave to dwell upon it for a few minutes.

Briefly stated, the jetty system may be described as the extension of the banks of the stream out to sea as rapidly as possible by substantial structures built upon the shoals on both sides of the axis of the discharge channel and extending this confinement of the flow beyond the crest of the bar. The immediate effect of this sudden acceleration of the current across the shoals is to scour out a channel to a depth which is dependent upon the width of waterway between the jetties. This deepening may be carried to an indefinite limit, even to the undermining of the artificial banks which induce it, by contracting the width of discharge, or lessened to any degree by locating the jetties at greater distances apart. On the completion of the jetties the formation of a new bar is immediately begun, presumably at about the same distance from the mouth as was the crest of the old bar from the natural shore line; but this new formation is modified by several conditions. First, the head due to the confined waters, being transferred to the crest of the old bar, diminished only by the slope in the length of the jetties, produces a greatly increased velocity at the exit into the open sea, increasing the momentum of the outflowing volume, as well as the length of the slope to sea level, thus carrying suspended material a greater distance. Then, as the bottom slopes downward, instead of upward as with the natural mouth, the sedi-

ment, having increasingly greater distances to fall through a heavier medium to the bottom, is deposited at greater distances than when the upward grade of the bottom, as great as one foot in five hundred, rises at every foot to catch the descending particles. Lastly, the lateral distribution, by the immediate discharge into deep water, is unimpeded by the shoals extending on each side to the natural bar, and the littoral currents have opportunity for their maximum effect in distributing the bar-forming material over more extensive areas. The rate of the current, one mile beyond the end of the jetties at South Pass, has been observed to be as great as 2.8 feet per second.

Thus theory would indicate a slower bar advance, and twenty years of experience with the South Pass jetties furnishes the unimpeachable testimony of facts. Mr. Donovan, United States Assistant Engineer, in charge of examinations and surveys at South Pass, has studied this bar formation very closely, and the results of his observations are extremely interesting.

In the nineteen years between 1876 and 1895 the greatest fill observed directly in front of the mouth of the jetties was eleven feet, at a distance of one and one-quarter miles from the entrance, where the original depth was about seventy feet. Comparing the distances from the end of the jetties to certain depths which existed before and since the improvement, it is found that it is now necessary to advance about 1800 feet further into the Gulf to reach seventy feet depth than in 1877; or, in other words, the seventy feet depth has advanced by shoaling about 1800 feet in about eighteen years, but the forty feet depth has moved seaward only about nine hundred feet in the same time. The greatest fill is therefore taking place in what was originally seventy feet depth at a rate of about 0.6 feet per year. In the same time the one hundred feet depth has moved from a distance of 6500 feet to 8000 feet out to sea. It does not seem reasonable that this shoaling in deep water should be classed strictly as bar-advance, as applied to the movement of the natural shoal; for, should this shoaling continue at the same rate, thirty years and more must elapse before the shoaling will reduce the navigable depth to thirty feet.

Considering, then, the failure of all other methods of obtaining a deep-water channel to the Gulf, and that the jetties at a moderate yearly cost for maintenance have given commerce a safe and reliable channel for eighteen years for vessels of even greater draft than it was designed to accommodate, there should be no question, at this time, when a wider and deeper water-way is demanded by

the increasing size of merchantmen and war vessels, that one of the three passes should be improved by this method to the required capacity. The only point to determine is, which of the three should be thus improved.

At first thought it seems simplest and most economical to increase the depth and width of South Pass, utilizing the work already done. There are, however, serious, and to my mind fatal, objections to the accomplishment of this. It will be admitted that the only means by which the Pass can be economically enlarged is by diverting more water into it. To do this it is necessary to increase the head of water above it, and prevent its seeking other routes to the sea, by partially damming other outlets and forcing it to take its course by the unobstructed pass. Any desired increase of volume could thus be added to South Pass, but when it is remembered that the scouring which would result would attack the banks as well as the bottom, it cannot be doubted that such a course would be hazardous. The banks of all these passes are perilously narrow in certain parts of their course, and only solid enough to afford a footing within a few feet of the edge, while the tide ebbs and flows over the sea marsh behind. So unstable are they that it is almost certain that they have settled an appreciable amount in the past twenty years under the weight of deposits yearly formed upon them. To increase the width of South Pass to much more than six hundred feet, which it affords now, would court the danger of a crevasse like that in Pass a l'Outre and the consequent destruction of the channel below it.

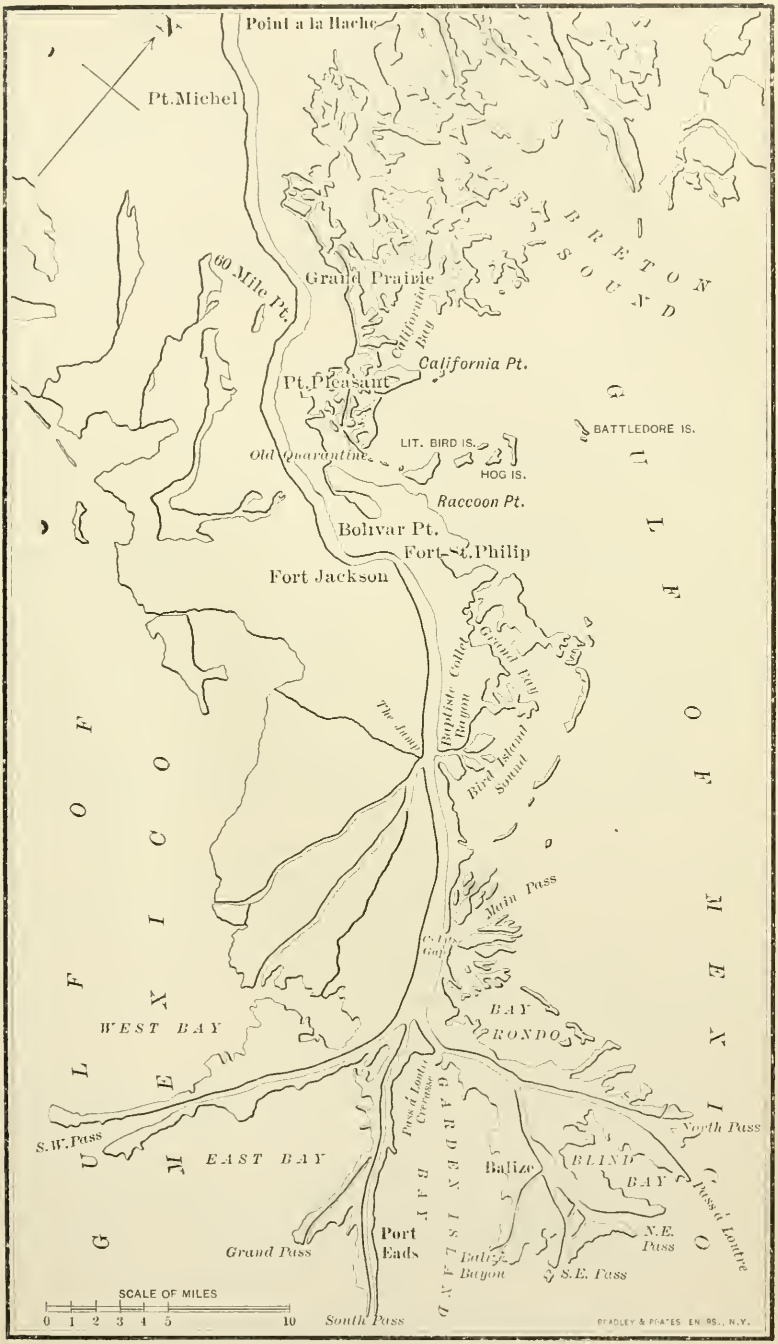
The jetties were built one thousand feet apart, and nine hundred feet of water-way is the most that could be obtained between them. This would involve the removal of wing dams and the inner parallel jetties built to maintain the present depth, while the danger of undermining would extend to the original jetties. These seem sufficient reasons for abandoning the attempt to enlarge South Pass beyond its present dimensions, aside from any considerations of cost. So deeply was Mr. Eads impressed with these possibilities that he seriously contemplated preventing its further enlargement at one time by throwing a sill across its head. If all repair work upon it were stopped now it would still, for years to come, accommodate all but the larger vessels entering the river.

Pass a l'Outre, for the upper third of its length, offers a sufficiently wide and deep channel to warrant the improvement of its bar, but below Southeast Pass, one of its outlets, its cross-section rapidly diminishes. This involves not only the closing of that outlet and of the more recent crevasse, at great expense, but it

means also the consequent shoaling, after this is accomplished, of this upper stretch by the diminution of its slope and the resulting check to the current. The enlargement of the lower stretch would certainly endanger the banks also, though to a less degree than in the case of South Pass. At the mouth, where two channels now exist, one of them would have to be closed by expensive works, and then, with these improvements to the pass itself, the jetties over the bar could accomplish a result incomparably better than could be obtained in South Pass.

We come now to the consideration of Southwest Pass. Recurring to what has been already said, it will be remembered that with a least width of 1200 feet, it carries a least depth of fifty-two feet through twelve feet of its fourteen miles of length, which is at least ten feet deeper than is found in six miles of Pass a l'Outre. It has no outlets of consequence from head to mouth, and its course is almost straight. The distance from Land's End to the crest of the bar is greater than that at Pass a l'Outre, but the course of the single channel across it is flanked by shoals with a maximum depth of nine feet, upon which jetties could be built. Finally, the improved channel at Southwest Pass would be sheltered from storms from any direction east of south, and, as few, if any, violent winds blow for any length of time from west of south, the harbor immediately inside of the jetties would be amply protected, and the channel less liable to injury than that at Pass a l'Outre, which opens out nearly due east. The most important of all these advantages is that of the great depth throughout the pass itself. The slope of the water surface, which, for a given cross-section, governs the rate of the current, is determined, of course, by the fall from the head of the pass to the Gulf level, and by the length of the pass. The Gulf level at the lower end is constant, within the limits of tidal oscillation, and the height of the river at the head of the passes is fixed at a maximum by the height of the banks. The maximum head of the river in flood stages at the Head of the Passes is about 2.5 feet, giving, for Southwest Pass, that much fall in its length of fourteen miles, less the small amount in the open sea. Should the pass be lengthened by jetties four miles, equal to twenty-eight per cent. of its present length, the slope and current would be proportionately reduced, and the pass would immediately begin to shoal to accommodate the new conditions.

In the case of South Pass the closing of outlets tended to produce a shoaling above them and a deepening below, while the lowering of the head by Pass a l'Outre Crevasse also caused a



THE MISSISSIPPI RIVER DELTA.

shoaling. Hence that due to the increase in its length alone cannot be ascertained. Before the break in Pass a l'Outre, however, a shoaling as great as fifteen feet had occurred in the deepest parts of the channel above the old outlet, and as much as eight feet below it. It is therefore essential that the original available depth in the pass to be lengthened should be as great as can be found, to allow for this certain shoaling. Southwest Pass, having, below the Head of the Passes, a least depth of fifty-two feet, affords ample allowance for this deterioration, while Pass a l'Outre, for six miles of its length, has a depth but little greater than that required for safe navigation.

In the absence of data furnished by detailed surveys, of course I have not presumed to estimate the cost of this improvement, but, remembering that the South Pass work cost the government $5,250,000; that experience with work of this character has largely reduced its cost; that the materials, such as brush and stone, could be obtained now at but little more than half the prices paid then; that much of the expensive work at the Head of the Passes would not be required for Southwest Pass, and that enormous rates of interest were paid for the use of money in a work of doubtful success, it cannot be doubted that, even with the greater work required for the greater pass, the cost would be much less. At Sabine Pass, to July, 1896, the two jetties, aggregating 34,000 feet in length, and of depth gradually increasing to sixteen feet, had cost $1,815,000, this including considerable dredging. Some 12,000 feet of this work was built in depths of nine to sixteen feet, and the construction has been done under small contracts extending over a period of sixteen years, adding greatly to the cost.

Southwest Pass jetties proper would have an aggregate length of about 40,000 feet, but the substantial work could be located in depths not exceeding nine feet, except at the extreme sea end, and lighter and much less expensive construction utilized to reduce the width as required, thus bringing the cost down to a sum comparable with that expended at Sabine Pass.

If what I have said in comparison of the three Passes is admitted as just, then the conclusion is inevitable that Southwest Pass is best adapted to the needs of navigation, and that the removal of its bar by the jetty method will afford the most advantageous, capacious and enduring water-way, with a width of fully 1200 feet, and a depth of at least thirty-five feet in the navigable channel.

MUNICIPAL CONTROL OF PUBLIC WORKS.

The Louisiana Engineering Society is not responsible, as a body, for the facts and opinions advanced in any of its papers.

By H. J. Malochee, Member of the Louisiana Engineering Society.

[Read before the Society, May 9, 1898.*]

Among the great changes which in the last few years have taken place in the distribution of population in this country, and, as a matter of fact, in the world, none has attracted the atttention of the political economists more seriously than the increased size of the cities. With this and other changes have come, and must come, corresponding changes in the law governing the two component parts of the state, the town and the country,—changes not only in the organic law itself, but in its practical application as well.

And in this practical application, in the urban life of to-day, in its comforts, health-giving improvements, rapid transportation, etc., the duties of the engineering profession are certainly on a par with those of any other professional calling, and the knowledge and advice of its members are in constant demand. Therefore, it is but natural that we should find ourselves discussing the question of municipal control of public works at this meeting, especially when we remember the active discussions which this subject has brought forth during the last few months in our own city.

Municipal control of public works does not necessarily imply ownership or operation,—yet this question is seldom discussed or even referred to, unless either one or both of these conditions are mentioned or insisted upon. Why should this general demand exist for municipal ownership or municipal operation? Why should such a number of good citizens organize in order to secure it? Possibly the answer to these questions is that, in the past, the means used by corporations to perpetuate their municipal contracts were such as to cause, at this late day, this general demand or this organization of citizens. Again, the desire of political power, or other selfish ends, might be the motives which prompt such movements.

The engineer, as a citizen, may or may not wish to deal with these conditions or with their causes, but as an engineer, adviser or designer, it becomes his duty to take into account all the conditions and circumstances which might affect the subject under consideration. Therefore I believe that if we are to consider this

*Manuscript received October 10, 1898.—Secretary, Ass'n of Eng. Socs.

question from the engineer's standpoint, all possible scope must be given to the discussion and every point pro and con can be and should be taken and duly considered.

In order to arrive at a general idea of the subject under consideration, let us pause and see the extent of the works which should be under municipal control; let us note their importance and the general method of construction and operation necessary to arrive at the best results. It is an obvious fact "that the science of city government includes administrative science, statistical science, engineering and technological science, sanitary science, educational science and moral science." Of these various branches of science none is more important, and surely none strikes home into the heart of the masses surer and deeper than that which deals with those public works which are in charge of the Engineering Department. Public works, as generally understood, include good roads for both streets and sidewalks, drainage, water works for drinking, washing and flushing purposes and for fire protection, sewerage, street cleaning and disposal of garbage, wharves and docks, belt railroads, parks and public squares, public lighting, street railroads, intercommunication systems by means of telegraph, telephones, etc. No one will question the great importance of all these works to the public at large, nor will anyone doubt that the government ought to have such control over the services as will, at all times, compel those in charge to maintain and operate them so that they shall be considered public benefactions instead of public curses, as has been the case in more than one unfortunate municipality.

All public works involve engineering ability of a greater or less degree, and that means, in the broadest application of the phrase, designing, planning, execution, all with one end in view, that of reaching a certain result. As a rule, any result can be attained, by using any one of several different methods, and the fact that by the method employed a given result is attained in a more or less efficient and cheap manner determines in a great measure the ability of the engineer. The man who designs is best able to have his design executed properly, and therefore when large works, covering a period of several years' construction, are contemplated, the designing engineer should be, under ordinary circumstances, the one charged with their execution.

I maintain that this is the fundamental principle which should govern any legislation or any scheme which has reference to public works, their construction, their maintenance, their operation. As all public works are more or less part and parcel of one general

scheme which has for its aim the comfort, convenience, safety, health and general welfare of the people, each particular department must be in accord with every other department, and all improvements and suggested changes must needs be in accord with the different parts of the general scheme which go to make up a grand, magnificent, efficient system—a unity.

And how can this be attained surely and safely, if not through the agency of a permanent corps of competent engineers and assistants?

The necessity of having a permanent organization to conduct any commercial enterprise has long been recognized, and it is strange that the people of this country, with all their well-known ability in trade and commerce, have not, to this day, understood this with reference to the municipal officers charged with the details of administration, design and operation of the commercial part of their municipal governments. It should have been recognized by the people years ago that permanent works, improvements which are to last several generations, must be evolved, constructed and maintained by a permanent organization, one which is not and cannot be disturbed on account of politics, or any other reason, except incompetency, malfeasance, corruption in office, and kindred crimes.

The permanent character of the organization charged with the details of the controlling power being recognized as necessary, the next step to consider is how to arrive at this result and obtain the best service for the least money. As the Mayor of Toronto recently said, while discussing the question of municipal ownership of water works in that city, the whole question "is a matter of business." If a city can get as good a service *in every respect* under one system as it can under another, yet obtain this service at a cheaper rate, then the cheaper system should be used. I say, in every respect, because the cheaper system might not be the best, as various objections, scientific, political and otherwise, might be inherent to the cheaper method.

Of the various plans adopted or suggested in order to arrive at correct municipal control of public works, the following might be considered as the most important, either on account of their extensive adoption, their novelty or their excellent points of recommendation:

First. We might mention the one probably most extensively used in this country, that of farming out privileges to private individuals or corporations for money or other consideration, the

municipality reserving its rights of police power and of party to the contract, but having no further control over the contractor.

Second. The slight improvement on the first plan, secured by injecting into that system such control as the right of executive officers to examine the books of the contractor, restricting dividends to a certain amount, the balance of profits being applied to a reduction of rates, to a division between the municipality and the contractor of the surplus, and so forth.

Third. The system by which the municipality builds, owns and operates all works through its executive officers.

Fourth. The leasing to contractors of the various works which belong to the municipality, the latter thus owning and, in some cases, maintaining the works, but leaving the risk, details and profit of operation to the contractor who pays a money consideration or a portion of the gross revenue.

Fifth. The placing of all common carriers and public servants under State Boards of Control, in the same manner as the Commonwealth of Massachusetts placed all the lighting companies under the control of a commission, with enormous powers for the regulation of rates, etc., thus placing safeguards around its corporate investments under which the right of the public and the rights of invested capital are both secured.

Sixth. The placing of all municipal works in the hands and under the control of a Board of Public Works, whose supervision embraces the construction, maintenance and operation of these works; this supervision being in some cases absolute, coming direct from the Commonwealth, and in other cases being such as to be partly under control, the Board of Aldermen having the final approval of plans involving extensive expenditures of moneys.

Seventh. The system that is used in Indianapolis for the control of natural gas supply or such a modification thereof as is thought best under the local conditions and laws. This system involved the creation of a self-perpetuating board of five trustees, who held no stock in any competing company, and whose selection was made with great care, so as to secure persons whose character and public spirit were such as to constitute a guarantee of good faith and business-like management. The subscriptions for stock in the company were received only upon the subscriber entering into a special contract, by which he named the trustees as his agents and as holding an irrevocable power of attorney to vote the stock subscribed for by him in elections for directors, and further, as soon as the holders of the stock or their assigns shall have received the

face value thereof, with eight per cent. interest, the service charges must be reduced to cost.

Each of these systems has its merits and its defects; and, strange as it may seem at first, the system best suited for one class of public works is possibly not suitable for another class. Again, under different local conditions, the same character of control might not be applicable to the same class of public works; yet it can be assumed, without fear of being contradicted, that in all cases municipal control is necessary; this premise is hardly debatable, but—what kind of control? As far as water works, drainage, sewerage, paving, wharves, docks, belt railroads, parks are concerned, it is doubtful whether municipal control in the shape of actual ownership and operation is even debatable, but municipal ownership of gas and electric light plants stands certainly on questionable grounds, while few, if any, think of street railways as fit subjects for either municipal ownership or municipal operation.

In discussing the several systems mentioned above, it is well to remember that all public works, more or less, use the streets of the municipality for the purpose of distribution, and, for that reason, if for no other, the streets must forever remain the free and absolute property of the municipality. Possibly this ownership of the streets might go so far as owning the various systems of distribution above and below ground and deriving rental from their use, although it is a matter of considerable doubt in my mind whether such ownership is always advisable.

It should not be forgotten either that there is a great difference between various so-called public works, in so far as the nature of the distributed material or energy in concerned. Water is a natural product, one which has no substitute, whereas gas, electric light and other such commodities are manufactured products, for which substitutes exist. In one case only distribution is required, whereas, in the other case, all of the risks, details and expert service necessary in factories of that character are required.

As a discussion of any of the various plans mentioned above would involve some points of interest in each of them, it is probably better to discuss them generally under such a caption as "Objections to Municipal Ownership and Operation" of the various classes of public works, while taking pains to bring forward the advantages as well as the disadvantages of each particular system for each particular class.

Taking the class of works which ought to belong to and be operated by the municipality, it is clear that, if the advantage of permanency in the technical corps in charge of such work is ad-

mitted, then there is no possibility of believing that these works can be safely left in charge of the executive officers of the municipality who are elected to political offices by political parties whose sole aim is the reaping of the benefits of the spoils system; therefore, the only systems of contròl admissible would be restricted to the last three, viz: control of existing corporations by public commissions; construction and operation by Boards of Public Works; or a co-operative system of public ownership, such as the Indianapolis system. But the question might well be asked, why should these systems be owned, and if owned, why operated, by the municipality? These works can be classed as natural monopolies brought about by the fact that the interests of the many are at stake, that the expenditure of millions is required for their establishment, and that little, if any, competition can be reasonably thought of in connection with the operation and maintenance of such works as water works, sewerage, drainage, belt railroads, parks, etc. These works are the results and the necessities of our urban life, necessities which are, in their nature, either the simple distribution or destruction of natural products, or they are requirements of trade which must of necessity be free to the people, or whose use must be so unencumbered that the municipality's right of ownership and control shall never be questioned.

Then again, the public health, as well as adequate fire protection, are to be considered, and if these matters are left to a contractor, then upon him partly devolve responsibilities which ought to belong directly to the government; responsibilities which, in a great measure, are part of the police power of the municipality, that power which has served as the key to many a serious and difficult situation.

If the privileges for these works are sold, or if their operation be leased to contractors, the rights of the two contracting parties must be protected; and, as contracts generally extend over a period of years, and as annulment of contracts are at best not easily secured, the changes necessitated by the rapid advances of the age, by the increase of population, by the demands of trade, must suffer either by waiting for more propitious times when the contracts shall have expired, or by being paid for at enormous advance over the real value of the improvements.

But the objections to the municipal operation of these so-called natural monopolies are not easily overcome. The organization necessary for this operation is as an army of office-holders, which stands like an insurmountable barrier to the will of the voters, one whose power can be broken down only by a revolu-

tionary uprising of the people. The government employe is always apt to believe that less is expected of him than is expected of the employe of any other corporation; and, notwithstanding our desire not to ventilate these facts, it happens very often that the incompetency of municipal officers is so patent as to evoke surprise even on the part of persons entirely unacquainted with the character of the work for which these officers are employed. The technical and commercial results attained by municipal plants are not generally of such a character as to warrant the risk and expense. All these objections might be true, and, if the proper precautions are not taken, they are bound to come true, but it is also true that various plans have been proposed and have been actually tried for years, by which all these objections can be overcome, whereby no political party shall be actually formed by the office-holders as against the tax-payers and other citizens, whereby the best talent can be secured to take charge of these works, for the reason that the permanency of the positions offered is assured to the office-holders and that no levy on their salaries will be made for election expense funds and the like.

Such systems as are used in Europe, where the efficiency of the municipal service has reached a maximum, mainly through the appointment of the most competent men to hold offices which are practically for life, through the expenditure of almost incredible amounts of money to secure the proper service, and by means of a system of civil service unknown to this country,—such systems, as well as others used in this country, have absolutely taken out of politics those public works which should be under the complete control of the municipal officers and have brought these services to a state of perfection which is astounding.

As to the other class of public works, which is said to be on questionable grounds, their ownership and operation by the municipality is not so easily discussed as the previous class, nor is a decision arrived at without considerable study of conditions, local as well as general. This question might well be considered under the following general headings, viz: The legal right of the municipality to engage in that sort of business; its moral right under existing circumstances; the expediency of that method of control. In discussing the legal right we would be expected to consider the terms of the charter of the municipality, its powers and duties as conferred by this charter, and therefore we must refer this part of the question to those versed in the laws which have reference thereto, and we now pass to the morality of the act.

The existence or the absence of a company engaged in the

business, holding a franchise from the municipality, changes the question of moral right very materially; so also is it changed according as the establishment of a plant for municipal use alone, or for municipal use and commercial supply is under discussion. The expediency of the installation of a municipal plant is dependent upon the legal, moral, financial and commercial aspects of each case, and can hardly be determined except by a general consideration of all the reasons for and against these particular views of the subject.

Examining the moral reasons in favor of and against the establishment of a municipal plant under the various aforesaid conditions, it is first to be noted that, at the time when the franchises for many public works were given, the establishment of these plants was accompanied by a greater risk than the average business should entail; in fact, a grave doubt existed in the minds of many well-posted advocates of these industries as to their ability to pay. Now, where a municipal plant is to be installed, if the city has, by direct or implied contract, caused the existing company to make such investments as were necessary to supply the city's wants, then this direct or implied contract carries with it at least a moral obligation to either purchase or pay for such apparatus, or so arrange matters that the company will not lose the capital so invested. This would be the moral aspect in the event that the city plant was to be used for city lighting alone, but where the city plant was intended to supply also commercial lights in direct competition with the already established plant, then it would surely be generally considered dishonorable in the extreme, for the reason that by such proceeding the entire power of the city would be used to compete with a part of itself, and that such action would tend towards the impairment if not the destruction of the capital invested in an enterprise which it had fostered and encouraged.

As previously stated, the expediency of the method of municipal control by the ownership and operation of public works is determined by the fact that the action contemplated is legal or illegal, moral or immoral, financially successful or commercially disastrous. As a general proposition, that which is illegal or immoral is inexpedient, and that is particularly true of a community at large; thus, the legality or immorality of an action would, in a great measure, determine the expediency of the municipality's actions with respect to the control of its public works.

To determine whether the proposed installation shall be a financial success or loss, we must first take into consideration the various plans proposed, and submit each individual case to one

thoroughly competent to make the necessary correct estimates; one who shall take account of every item, large or small; one whose estimates shall not be guided by his sentiment and prejudice. It is then necessary to compare the conditions existing, and especially those apt to alter these estimates, in the light of previous experience by careful comparisons between the proposed and already established plants.

One of the arguments used assiduously by the managers of existing plants is one mentioned previously in reference to the comparatively small amount of work done by municipal employes, and the relative incompetency of these employes; but this is generally incorrectly stated in such a way as to appear as though it was impossible to have faithful and competent men in the public service. Such men may be got by the municipality, but such is not the good fortune of many municipal governments; and, further, even when these services are secured, these men, after a time, become generally lax in their duties. The experience of the average municipality is that less work is done by its employes, simply because it becomes a custom among them to do less than they would be expected to do for any other corporation. In fact, they consider themselves privileged characters, whose positions confer on them certain rights over and above the rights accorded to other persons in similar positions.

The third class of public works, which are seldom considered as fit subjects for municipal ownership, must yet under all circumstances be under municipal control. Taking as an example the street railroad, we first find, in large communities, innumerable parallel lines, lines which have little if any reason to exist, lines which mean the duplicating of investment without any real benefits being derived therefrom by the traveling public; in fact, whose duplicating has been in many cases a source of poorer rather than of better service.

Then we note the question of improvement of equipment, reduction of fares, etc., all of which are discussed without special knowledge of the circumstances and without regard to the justness of the demands. Public investigations are held by committees of men without experience in the details connected with the operation of such works, often without any well-defined idea of the public requirements; the publication of these investigations is read by men able to examine them only through the lens of a biased mind, or by others who are entirely unacquainted with the methods necessary in handling large financial schemes, and the result is a still greater separation between the public and its servant corpora-

tions, until the time comes when all the rights of these corporations are so abbreviated as to force them to the wall and a complete annihilation of the capital invested is arrived at.

It seems reasonable to suppose that the best method in cases of this kind is that regulation of all complaints and evils by a system of control such that the general methods of government of these corporations are known to the public at large, being made so through reports to properly constituted commissions, it being understood that all minor details are eliminated from these reports, yet are subject to private investigation by the commissioners, and that the decision, and not the evidence in each individual case, shall be published. If the characters of the members of these commissions are such that their decisions carry weight and confidence, and that their motives shall never be questioned, then the solution of the major part of the difficulty is within the reach of those who desire it; then the people and the public servants will be brought into a closer bond of friendship; then the corporate as well as the public interests will be protected and the desired end reached.

The regulation of public corporations by trade competition has been tried, but such method has generally resulted in several evils, such as duplication of equipment, with its increased capitalization and increased cost of operation, combinations of interest and consequent advance in prices, division of territory with the same general results, demoralization of the municipal officers through the endeavors of the competing corporations to secure favors at their hands, and many more objections which are more serious than the ones due to a monopoly, even if that monopoly has no restraint placed upon it by proper municipal control. Thus we come to the conclusion that, in so far as concerns that class of public works wherein the service is extensive yet personal, the employes numerous, the labor of high grade, the management technical,—such service as that of street railroads,—it is much better in the hands of a private monopoly, whose franchise is perpetual, whose operations are controlled by a commission representing the municipality's best interest; all this, coupled with a system of perpetual profit-sharing with the city, joined with a remission of charges whenever the profits come to be sufficient for the purpose.

A careful consideration of the foregoing will prove that *each* class of public works must be controlled in a different manner, and that, under varying conditions, the method of control will not be the same. Another thing proven is that technical matters should be handled by men whose special knowledge eminently fits them for the position they fill, and therefore that politicians should not

have the naming of the officers who occupy technical positions. It is also proven that these men should have permanent positions, thus combining several advantages, such as uniformity of design in the general plan, correct understanding of the details involved in the general design, ability to devote entire time, talent and attention to their duties without being called upon to make combinations with politicians in order to retain their positions, thus causing in them a feeling of dependence and subserviency, which would produce a warping of their judgment by considerations which ought never to be allowed to enter the minds of technical officers.

The examination of technical reports, the study of problems for the betterment of the public services, the necessary investigation to determine whether such betterments are possible, the reports on subjects relating to details in the management, the tests necessary to ascertain whether contract obligations are being carried out in conformity with the contract; in fact, almost everything that relates to public works is, as a rule, referred to the engineering department for a decision and report as to facts, technicalities and advisability, thus placing the responsibility of control in a very great degree upon the municipality's engineering staff. This responsibility proves that the opinions of engineers on the subject of municipal control of public works are entitled to more weight than those of the average citizen; that legislative schemes which do not embrace their ideas on the subject are apt to be incomplete or unsatisfactory in the end; and as this Society is the authoritative organ of the engineering profession of the State of Louisiana, it therefore becomes its duty, as representing one of the professions most interested, to express itself on this important subject, which is now occupying the attention of the Constitutional Convention and of our community.

Let this expression take whatever form the members think best, but, in justice to ourselves and to our noble profession, let it be scientific, technical, honest and true, and when the perfect control and regulation of municipal works shall have increased the healthiness of our already healthful surroundings, paved our streets, increased and bettered our water supply, improved our drainage, secured to our city the commerce to which she is entitled, —when all these permanent improvements, which will go to make up the jewels of her crown as queen city of the richest valley in the world, shall have been secured, then will the future generations who will enjoy and reap the benefits of all this work forever sing the praises of those whose combined efforts shall have made those superb achievements possible.

SULPHURIC ACID AND THE BY-PRODUCTS FROM IRON PYRITES.

By R. G. Ewer.

[Read before the Detroit Engineering Society, February 19, 1897.*]

Before describing the present mode of manufacture of sulphuric acid it may be well to give a hasty glance at its early history.

Basil Valentine, of Erfurt, Prussia, born in 1394, was the first to mention sulphuric acid, and his writings show him to be well acquainted with its preparation and use. There is evidence, however, that it was known a long time previous to this.

Sulphur was used in the time of Pliny for making matches and for bleaching purposes, by being burned in a current of air.

An Arab named Geber obtained sulphuric acid by distilling alum in the eighth century.

Although acquaintance with sulphuric acid began so early, it was not until 1570 that anything like a correct description of it was given. At that time such a description appeared in the publications of Gerard Dornæus.

Sulphuric acid is found naturally in many springs in connection with volcanoes, and in these cases is without doubt derived from the burning of sulphur in these districts together with slow oxidation.

The early English makers made their acid by the distillation of "green vitriol" in earthen vessels, known as "long necks." Fifty or more of these were arranged in a reverberatory furnace and connected with glass receivers by means of luting.

Copperas works began in England at Hastly in 1748, and at Walker in 1797. After drying the copperas was distilled off by being laid in a brick oven and subjected to a strong heat; the gases, upon being condensed, formed an impure oil of vitriol. If one ton of copperas produced 1½ cwt. of acid it was considered a fair result. The price was two shillings (or say 50 cents) per pound. The prices ruling during 1895 have probably been considerably less than one-half cent per pound in wholesale quantities.

This process, owing to the expensive repairs made necessary by the intense heat required, was abandoned and the use of sulphur and nitre was adopted, the ore being burned in glass globes and the output concentrated in glass retorts or other vessels. This method was first introduced into England by Dr. Ward, who

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called his product "oil of vitriol made by the bell," and on account of its superior quality sold for the equivalent of from 37 to 62 cents per pound.

About the year 1746 leaden chambers were introduced by Dr. Roebuck and his partner, Samuel Garbett. Three years later these gentlemen made extensive experiments on the Eastern coast of Scotland, and the results of these experiments were published by Dr. Home, of Edinburgh, and led to the use of sulphuric acid for bleaching purposes. Sour milk had been used previously. A great demand was created for such acid for this purpose, and in 1790 England exported 2000 tons.

From this time great was the variety and size of leaden chambers, round, square, long, short, high and low, until the dimensions of the chambers which may be classed as representative of the best practice of to-day are from 80 to 100 feet long, 30 to 40 feet wide and 18 to 20 feet high. Departure from these sizes will be found in the best practice, but the sizes given above will be found in the great majority of cases.

In the early history of the manufacture of sulphuric acid 7 or 8 pounds of sulphur was mixed with one pound of saltpetre, and 300 cubic feet of chamber space was supposed to be required for one pound of this mixture. The sulphur and saltpetre mixture was burned upon hot plates, arranged upon a platform in the chamber a foot or so above the water, the chamber being filled to 6 or 8 inches in depth with water.

Mr. Park, in his "Chemical Essays," refers to the next improvement as a separate apartment in which the sulphur was burned. By this method one pound of sulphur gave 2¾ pounds of sulphuric acid of 1.848 specific gravity. This separate apartment or oven was round in form, made of fire bricks 4 to 5 feet diameter, having its floor 2 feet from the ground and an arched roof, the highest point being 2 feet from the floor. The front was supplied with a sheet iron door, and in this door a tin slide was arranged to admit the necessary air. The sulphurous gases were led off by a 12-inch iron pipe, extending from the roof of the oven and connecting with the chamber.

The next improvement was in making bricks of the sulphur paste, weighing about 20 pounds and dried on the top of the oven. With this improvement came the introduction of nitre in pots. The saltpetre was used in proportion of 1-10 of the sulphur, with sulphuric acid enough to make the proper decomposition, the residue from the pots being sulphate of soda or salt cake, or, more properly speaking, nitre cake. The gases entering the chamber

were cooled by water allowed to drop into it. Kestner, in 1828, introduced the use of steam in the place of water in the chamber. He also invented the "drop tube" for collecting the acid in the chamber for testing the strength.

Up to this time all gases passing uncondensed from the chambers were carried into the work chimney and thus diffused, to prevent as far as possible injury to vegetation.

The great change in the history of the manufacture of sulphuric acid was the substitution of pyrites for sulphur, and was made necessary in 1833, when the King of Naples granted to Messrs. Taix & Co., of Marseilles, a monopoly of the Cicilian sulphur trade, from which cause the price of crude sulphur advanced from $20 to $70 per ton.

Thomas Farmer, in 1839, was the first in England to use pyrites, although it had been used somewhat earlier in France. It is said that a Mr. Hill, of Deptford, had used sulphuret ore instead of sulphur in 1818 in an experimental way.

Spanish pyrites were used in 1856, Belgian in 1858 and Westphalian and Norwegian in 1861.

The first platinum retort appears to have been used in London in 1809. It weighed 423 ounces, and was very costly.

Previous to the introduction of platinum glass retorts were used for the concentration of sulphuric acid to oil of vitriol, but, as the expense caused by breakage was great, both in apparatus and in loss of acid, and as the suffocating vapors caused thereby were very annoying, the platinum retort, costing $10,000 and over, was used when the expense was not beyond the limit of the capital invested.

The manufacturers of platinum stills or other platinum apparatus are few, and, as the Russian Government holds a monopoly of the platinum mines (the only source of supply at present is found in the Ural Mountains), the prices for chemical apparatus made from this material are likely to continue at a high figure.

The latest improvement in platinum stills is referred to in a circular letter of W. C. Heracus, of Hanan, France, represented in New York by Charles Englehard, where the platinum surface exposed to the acid is gold-plated. The plating decreases the loss of platinum from 0.05 gramme in the case of pure platinum to 0.01 gramme in the case of gold-plated platinum. M. Heracus considers that the practical results obtained by gold-plating under his patent establish without further question the superiority of this method over all others.

The making of sulphuric acid from sulphur is a thing of the

past in this country, except where chemically pure acid is required. The system of manufacture, however, is similar to that described, minus the towers which are now universally used and will be described further on.

Iron pyrites are obtained from several sources in the United States. In fact, almost every state in the Union contains some pyrites. The principal sources from which our manufacturers draw their supply for acid making are Franklin County, Mass., Louisa and Prince William Counties, Va., and Paston County, N. C.

Since the year 1882 there have been mined in the United States 973,480 tons, the prices of which have declined from $6 per ton in 1882 to $3.24 per ton in 1895. Since 1889 the average yearly production has been about 100,000 tons, except in 1893, when it fell to 75,777 tons.

Little positive information can be obtained respecting the importation of pyrites for acid making previous to 1891, as all ores containing sulphur were classed as sulphurets. Since 1890 our Government has carefully separated these ores, so that it is now an easy matter to ascertain precisely what ores are used for our purpose. Since 1890 there have been received in the United States for acid making purposes 901,922 long tons, containing not more than 3½ per cent. of copper. Consequently it is allowed to enter duty free. The importations yearly and the prices for same have been as follows:

In 1891, 100,684 tons at $3.80 per ton of 2240 pounds.
In 1892, 152,359 tons at $3.86 per ton of 2240 pounds.
In 1893, 194,934 tons at $3.70 per ton of 2240 pounds.
In 1894, 163,546 tons at $3.62 per ton of 2240 pounds.
In 1895, 190,435 tons at $3.53 per ton of 2240 pounds.

The annual consumption of pyrites during these years was as follows:

	1891.	1892.	1893.	1894.	1895.
Domestic	106,536	109,788	75,777	105,940	99,549
Imported	100,648	152,359	194,934	163,546	190,435
Total	207,184	262,147	270,711	269,486	289,984

The supply from abroad is usually received from the Rio Tinto Company's mines in Spain, and contains, as an average, 48 per cent. sulphur, from 3 to 3½ per cent. copper, from 1 to 2 ounces of silver and about 1-10 of an ounce of gold, ¼ of 1 per cent. of arsenic, with traces of other metals, such as zinc and lead, the balance being iron ore, which, when separated, will test 67½ per cent. iron.

The Pennsylvania Salt Manufacturing Company, of Pennsylvania, imports the most, if not all, of the Rio Tinto pyrites, owing to their immense plants, by which they recover the silver, gold and copper as well as the iron from these pyrites. They not only import for their own direct consumption, but sell to other manufacturers of sulphuric acid, allowing them, for a consideration, to return the cinders after the sulphur has been burned off.

Formerly these pyrites were sent here in lumps of irregular size, and were crushed by the consumer; the crushing caused a considerable amount of "fines," which were difficult to burn in any quantity with the regular ore, as the fine material will clog

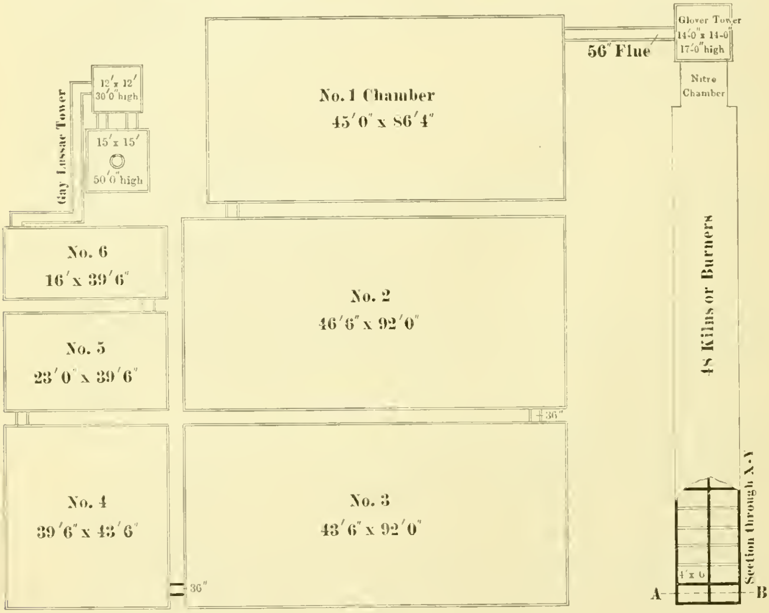

Fig. 1.
Arrangement of Chambers and Kilns.

the kiln and prevent a draught, causing the fires to burn low or die out entirely. Of late years it is the custom to purchase the ore already broken to size suitable for the kiln, and in this way there are little or no fines to be cared for.

The kilns, Figs. 1 and 2, in which the ore is charged regularly are made of brick, about 4 feet by 6 feet by 4 feet deep above the grate, and are set back to back in benches of twenty or thirty. The number of kilns will depend entirely upon circumstances. The numbers mentioned are usual in laying out new work. The writer has worked as many as 55 kilns in one set of chambers, the circumstances in that case having been such that it was preferable

to do so rather than attempt the separation of a large plant of old sulphur chambers.

These kilns are provided with full cast iron fronts covering the whole surface front of each kiln, and as the kilns are placed back to back there is an unbroken line of cast iron on both sides. The fronts are bound together by railroad iron buckstaves at the points where the fronts join each other. This makes a most effective binding, and the life of a kiln is in this way preserved for many years. Internally these kilns resemble a square box with a grate of $1\frac{1}{4}$-inch square wrought iron bars located above an ash or cinder pit 2 feet from the floor. The roof is arched directly over each kiln, and a second arch above this extending over both lines of kilns gives a suitable flue through which the sulphurous gases are conveyed to the Glover tower, Fig. 1. Each kiln is charged with the amount of pyrites it will successfully burn in a given time.

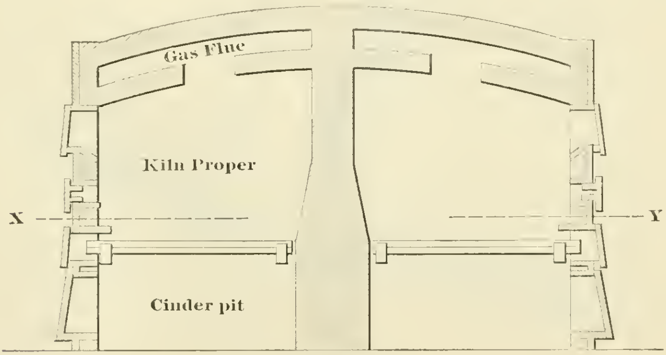

FIG. 2.
SECTION OF KILN THROUGH A-B.

The kilns are charged in turn and as rapidly as possible, to prevent the admission of excessive air. The charging is done through a door in the fronts, arranged for the purpose, and the cinders are withdrawn from the pit before the charging is done. A crank, adjusted to the end of the grate bar, whereby each bar is rocked in succession, is the means for shaking the cinders into the pit. Sliding dampers in the pit doors allow of the proper regulation of draught, and a peep hole in the charging door allows of inspection of the interior of the kiln. In the center of front, below the charging door, is a circular hole, which is ordinarily filled with fire clay, but which, when required, serves for breaking up the ore in the kiln. This is seldom needed with even-sized pyrites, but when "fines" are used it is found very convenient. The gases evolved by the burning of the sulphur contained in the pyrites pass up through a hole in the roof arch into the flue above. At the

extreme end of the bench of kilns, and between them and the Glover tower, is arranged a nitre chamber, where the pots or vessels are arranged for distilling the nitrous gases which combine with the sulphurous and enter the tower on the way to the chamber. The combination of these gases in the presence of water causes a reaction, converting the sulphurous into sulphuric acid.

The Glover tower was invented by Mr. John Glover, of Wallsend, near New Castle, England, in 1859. It consists usually of a square structure made of heavy lead sheets, supported by a suitable framework about 10 feet square and 24 feet high. The lead walls are lined by acid-proof brick and filled with checker work of same material. This tower sits upon a foundation of brickwork usually built to the proper height and in a heavy lead saucer. The

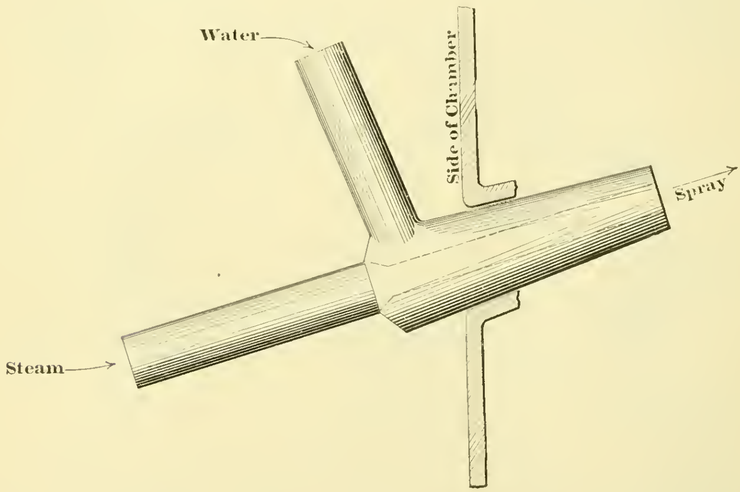

FIG. 3.
DR. SPRENGEL'S ATOMIZER.

gases, as they enter the bottom of the tower and ascend, are met by a shower of nitro-sulphuric acid, which is distributed from above by means of an ingenious arrangement of pipes from a distributing box. By this means the hot gases are cooled and the weak acid from the chambers is strengthened from 45° to 55-60° Beaumé, while the nitrous acid becomes denitrated. The gases not condensed in the tower pass over into the first chamber, together with the water evaporated from the weak acid and the nitrous gas. The arrangement of chambers is usually made to suit the convenience of location. In the writer's experience a variety of sizes and styles of arrangement have been used, varying in width from 34 to 44 feet, in length from 24 to 100 feet and in

height from 18 to 25 feet. The arrangement and size of chambers shown in Fig. 1 was designed and constructed by the writer in 1892, in connection with a complete plant for pyrites, and has given the greatest satisfaction of any in his experience. They have a capacity of 276,799 cubic feet, and are only 18 feet high.

Professor Lunge says, in his "Sulphuric Acid and Alkali," that all the work of a chamber is done midway between the top and bottom and first half, and this is borne out by the writer's experience. In order to effect the proper reaction the sulphurous and nitrous gases must be brought together in the presence of water, and water in the form of rain was first used but rendered the acid so weak, if enough water was used to produce the necessary condensation, that a large expense was involved in again concentrating the acid.

To obviate this trouble Kestner, as stated above, introduced a jet of steam, entering the chamber in such position as to assist the current forward to the next chamber. Dr. Sprengle, in 1876, introduced a patented form of spray nozzle, Fig. 3, in the sides of his chambers, about 40 feet apart, and with 20 pounds of steam was enabled to convert 80 pounds of water into a cloud-like mist at the rate of 750 pounds in twenty-four hours. By this method he claimed a large saving in fuel over that required for producing steam for the purpose. Professor Lunge gives as necessary for chamber service $1\frac{1}{2}$ pounds of steam per pound of sulphur burned. The writer's experience would place the figure at $1\frac{1}{3}$ pounds where the boiler is reasonably near the chambers and the pipes are properly protected from condensation.

While the work of oxidation is carried on principally in the first half of the chamber, and while practically the last half does no work, yet as soon as the gases are again drawn together in passing through the connecting pipe into the next chamber the work proceeds again for about one-half of the next chamber.

Lights of glass, arranged in either side of the chamber against the light from a window, show the working of such gases. The writer is of the opinion that a series of dishes, like dinner plates, for instance, piled across the chamber as a perforated partition about midway of the chamber, with the plates so piled as to leave reasonable interstices through which the gases could pass, meeting with a constant dripping of weak acid from the overflowing plates, would effect a better intermixture and cause a more rapid reaction, thus accomplishing a greater amount of work per cubic foot of chamber space.

The set of chambers above mentioned were supplied with 48 kilns, consuming the sulphur from 16$\frac{2}{3}$ tons of pyrites per diem. This is equivalent to 7$\frac{2}{3}$ tons of sulphur, and with this was used 345 pounds of nitrate of soda, equal to about 2$\frac{1}{4}$ per cent. of the available sulphur contained in the pyrites,—*i.e.*, 46 per cent. of the 48$\frac{1}{2}$ per cent. originally contained. The reason for the extremely low percentage of nitre will be explained further on in connection with a second Gay Lussac tower.

Each chamber should be supplied with a thermometer and drip tubes. The temperature and the test of strength of the chamber acid should be recorded every hour.

As the remaining gases in the last chamber are and must be highly charged with nitrous gases, there would be a great loss of nitre as well as destruction to surrounding vegetation if these gases were allowed to escape. To accomplish the saving of this nitre Gay Lussac invented a denitrating tower, called, after him, the Gay Lussac tower. Although he made the invention in 1827, it was nearly forty years afterward before it was put into use, and no acid manufacturer of magnitude is to-day without it. This tower is similar in style to the Glover, but is filled with large pieces of hard-burned selected coke instead of chemical bricks or flints.

These towers are usually from 8 to 15 feet square, and from 30 to 40 feet in height. Professor Lunge says their cubical capacity should be about 1 per cent. of the chamber space, but our experience with the plant above mentioned shows that 2$\frac{1}{2}$ per cent is better, in the form of two towers.

The escaping gases pass up through the coke, where they meet with a fall of strong acid, distributed as in the Glover tower, and then escape to the air. By this means a saving of at least two-thirds of the nitre is made, and a large portion of chamber space is saved as well. The acid used in this tower becomes, of course, highly charged with nitre, and is used with chamber acid in cooling the Glover tower where the heat liberates the nitre, and it passes again to the chambers and is absorbed as before described.

In the plant above mentioned a second Gay Lussac tower, 15 feet square and 50 feet high, was used. The gases from the last chamber were sent through the first tower with a down-draft and entered the second tower at the bottom with an up-draft. This reduced the quantity of nitre to less than 2$\frac{1}{2}$ per cent. of the sulphur burned, with a chamber space of 19 cubic feet per pound of sulphur burned and a yield bordering on 300 per cent. of acid, 306 per cent. being the theoretical maximum. The writer does not claim the

idea of this second tower as original with him, as it had already been used, in one instance at least, in England.

The acid from chambers and towers is run into tanks lined with lead, and from them transferred to any part of the works desired by means of a receiver (called in England *an egg*) and by air pressure. Strong acid,—*i.e.*, oil of vitriol, can be stored or transported in plain wrought iron tanks, unlined, but the weak acid must have lined tanks. The weaker the acid the more rapid is the oxidation of the iron. The transportation of strong acid is almost entirely done in tank cars or boats of such shape and strength as to permit of their being discharged by air pressure.

The chamber acid from Spanish pyrites contains an amount of arsenic, in the form of yellow oxide, which must be removed before it goes to market, ordinarily, or to the platinum stills, and this is done by means of the Friburg tower. Here the acid, meeting a current of sulphuretted hydrogen made from the sulphide of iron, precipitates the yellow oxide. In this way the acid is freed from 85 per cent. of all the arsenic contained, and this percentage is sufficient for all ordinary trade purposes. Sulphuric acid made from arsenious ores is never used for medical purposes.

To concentrate the acid further to oil of vitriol it is necessary to use the still. In connection with the still is a series of pans of heavy lead, arranged in steps so that the acid fed into the first pan will overflow into the second, and so on until from the last it flows into the first or upper pan of the still. These pans are set on brickwork, over which are placed iron plates for the support of the pans. Under the lower pan, next the fire, it is necessary to have checkered arches of fire brick to prevent the action of excessive heat against the lead bottom. The fires from the stills furnish the heat for the pans.

The still is made either of platinum or of iron, or both. The iron still is of recent date, and answers very well for coarse acid; but for clear, fine acid the platinum still is required. The most acceptable style of platinum still in use to-day is in the form of a pan, not unlike a milk pan, about 36 inches in diameter and 6 inches deep, with a lead cover or hood arranged to receive a copious supply of cold water over its surface. Formerly three of these platinum pans were used as forming one still, but at present I believe only two are used. At least, where natural gas is used as fuel two were found sufficient. These stills are set like the pans, and overflow from one to the other.

The acid is fed into the first of the lead pans at from 48 to 50°

Beaumé, and in its course to the still becomes concentrated to about 60°, when it enters. It leaves the second still at 66°.

The iron still is used in a similar manner, except that only one iron still is used in place of two platinum stills.

The cinders containing the remaining sulphur, the difference between the original 48½ per cent. and the 46 per cent. which has been converted into sulphuric acid, is ground with salt to pass through a 20-mesh screen. The old chaser mill seems to answer this purpose better than any of more recent invention. The wear and tear is heavy, and the more cumbersome the mill the slower is the motion and the longer is its life. From the dry cinders, which are composed principally of the red oxide of iron, dust arises in clouds about the mill, and the manipulators resemble rather the red men of the forest than white laborers.

After grinding, the fine cinders are charged into muffle furnaces and roasted; and the remaining sulphur, in combination with the chlorine of the salt (with which the cinders are ground), is driven off in the form of gas and condensed in towers especially arranged for this purpose, giving a weak solution of hydrochloric acid which runs into storage vats. The roasted cinders are taken directly from the furnaces by iron wagons and dumped into leaching vats for the purpose of removing the silver, gold and copper. After filling the vats with roasted cinders the vats are flooded with the hydrochloric acid from the storage supply and allowed to stand until the liquor has taken the copper and precious metals in solution, when it is drawn into precipitating vats, where, by the "Claudet" process, the silver and gold are thrown down by iodine; after which the remaining liquor containing the copper solution is drawn into another vat in which scrap wrought iron is deposited and allowed to remain until the iron has gone into solution and the copper has taken its place in the form of "copper cement," which is dried and smelted in the ordinary manner. Where we had a solution of copper we now have a solution of iron, which, upon being concentrated and allowed to crystallize, gives sulphate of iron or copperas crystals. The silver precipitate or "mud," as it is called, is dried and put into Doré bars or sold as mud containing so many ounces of gold and silver as determined by analysis. The remaining iron in the leaching vats is withdrawn, allowed to drain on a table prepared for it and then dropped into railroad cars for transportation to market as iron ore. This method of extracting the metals from the pyrites cinders is called the wet or Henderson process. So far as the writer is aware, it is operated only by one establishment in this country. It is an exceedingly dirty process,

but very fascinating, as most chemical processes are. The wear and tear upon all parts are excessive. Iron cannot be used in connection with sulphuric acid in its weak state, lead being the only material, except glass and platinum, that can be used. In many parts of the work glass cannot be used, and platinum is expensive. Neither lead nor iron can be used in connection with hydrochloric acid. Either stone or wood must be used here.

Vats are usually made of wood, with double sides, ends and bottoms, and the space between say 1½ to 2 inches is filled with pitch cement and the whole interior painted with hot hard pitch. All joints where stones are used are made of rubber protected by pitch, and their interior surfaces are painted with the same material. All woodwork is put together with tree nails and bound on the outside with iron rods and painted with pitch. The average life of such work scarcely exceeds eight years.

A *résumé* of the foregoing shows that out of the Spanish pyrites all the sulphur is converted into sulphuric acid (or hydrochloric acid). The copper, silver and gold are saved to within 2 to 3 per cent. of the total contained, and a large portion of the iodine used is recovered. The scrap iron for obtaining the copper is returned in the form of copperas. While the original iron ore contained in the pyrites is saved and used by blast furnaces, this ore, as stated above, is of 67 per cent. iron, and known as "Blue Billy" or "purple ore." It can be ground and used successfully as an iron paint.

For many points in the early history of the manufacture of sulphuric acid the writer is indebted to Professor Lunge's "Sulphuric Acid and Alkali," and Mr. Charles T. Kingzett's "History, etc., of the Alkali Trade," and for statistics to Mr. E. H. Parker's report for 1895 to the Department of the Interior.

Longitude West from Greenwich
CANADA
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MONTANA
MINNEAPOLIS
ST. PAUL
DENVER
PACIFIC COAST
ST LOUIS
DETROIT
CLEVELAND
BUFFALO
BOSTON
Philadelphia
VIRGINIA
LOUISIANA
GULF OF MEXICO
MEXICO
PACIFIC OCEAN
ATLANTIC OCEAN
WASH.
ORE.
IDAHO
MONT.
WYO.
N. DAK.
S. DAK.
MINN.
WIS.
MICH.
IOWA
NEBR.
CAL.
NEV.
UTAH
COLO.
KAN.
MO.
ILL.
IND.
OHIO
W. VA.
VA.
MD.
DEL.
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ME.
N. C.
TENN.
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THE EVOLUTION OF STRUCTURAL DESIGN.

BY F. T. LLEWELLYN, MEMBER OF THE LOUISIANA ENGINEERING SOCIETY.

[Read before the Society, September 19, 1898.*]

IT is the purpose of this paper to show how the development of Structural Design is due rather to varying and improved conditions governing cost and availability of material than to more perfect knowledge of the theories of mechanical statics. The writer does not intend to treat of ornamental design, with classification and details of the various forms and mouldings adopted under historic régimes, but will endeavor to restrict himself almost entirely to that part of design (especially frame-design) which by the use of the most effective and economical materials overcomes such natural forces as those exerted by dead and live loads, wind pressure and the effect of heat and cold, and he feels that it is not unsuitable for him to take up such a subject, on account of his double duties in both contracting and engineering; in combining which the truth of his initial statement is being frequently evidenced. The principal authorities consulted have been Ferguson's History of Architecture, Cooper's American Railroad Bridges and Weale's book on Tubular Bridges.

Going back to the earliest civilizations, we find that their roofs and arches show most plainly the action of the above-stated principle. In Egypt the most primitive structures had each opening spanned by a single stone, in many cases of great size.

*Manuscript received October 24, 1898.—Secretary, Ass'n of Eng. Socs.

Their temples consequently show the ruins of many interior supports; but mystery and gloom being so large a part of their religion, the multitude of heavy stone columns covered with hieroglyphics was congenial rather than otherwise. There is no evidence that their old temples were roofed in any other way than by single stones, although structures of later times show signs of arched coverings.

The Greeks and Romans often used the same method, and have left one example, the Mausoleum of Theodoric at Ravenna, which has a domed roof formed of a single stone nearly 35 feet in diameter,—a size which makes us think meanly of this century's masonry. The Greeks also used wooden beams as roof supports, which have almost entirely perished, but their construction was luckily copied in the stone friezes which remain to-day, wherein the ends of the rafters with all the necessary cleats and nails are reproduced in the carved masonry.

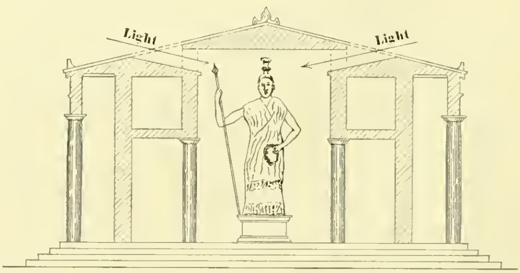


FIG. 1.

Their temples seem to indicate a very ingenious mode of lighting the interior without impairing the harmony of the exterior, which might teach a lesson to some of the builders of our older office blocks.

The inside of a Greek temple contained nothing but a statue of the patron god, upon which it was very desirable to cast a good light, the roof being arranged as in Fig. 1.

To the Romans we owe the elaboration of the arch,—*i.e.*, the radiating arch,—for there was among the Hindus a very different kind of arch in use. Not very many of the oldest Roman buildings were covered in this way, but it was used extensively in tombs, drains and treasuries. It is easy to see how the arch came to take the place of single huge stones, such as were employed by the Egyptians. The only way in which such heavy pieces could be handled, without the use of machinery, was by working hundreds of people, who had to spend their lives in lifting. Egypt had thou-

sands of such able-bodied and ambitionless slaves, while Rome in the earliest times owned very few slaves, and later they were so weak and effeminate that such tasks would have been impossible. The rocks themselves also were more readily used in smaller pieces. The evolution of the arch was like this: First, a single stone beam was used to span an opening, then, when the length became too great, two stones were inclined together, and soon a third was added, which we now call the Keystone, and with more skilled masonry work the number of stones was increased as shown in our own arches. (See Figs. 2-5.)

In India there are arched roofs built on an entirely different principle. Such examples as have just been described cause an outward thrust at the spring, more or less great according to the span and versed sine, which has to be overcome by the dead weight

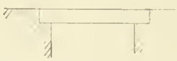


FIG. 2.

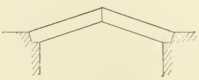


FIG. 3.

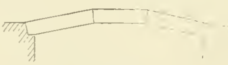


FIG. 4.

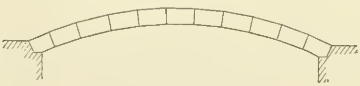


FIG. 5.

on each side. The joints all pointing to a common center, they are called radiating arches.

This outward thrust was altogether distasteful to the Hindus (they have a proverb that "an arch never sleeps"), and so they built what is called the horizontal arch, which in section looks like a number of cantilever brackets, but is not so.

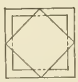


FIG. 6.

They first employed the simplest method of covering a space with a single stone, thus: but for the ordinary use that practically limited their openings to about 4 feet square; and so they filled the corners with four triangular stones, resting the single stone upon them; and so covering a space of about 6 feet square without using a stone bigger across than 4 feet. (Fig. 6.)

With an increasing number of stones, extra supports were found necessary round the sides, but leaving a clear space in the center of sometimes 40 feet square, which would look like Figs. 8 and 9.

Such an arrangement will of course bring quite a bending moment on the lower course of stone, but there will be no outward thrust.

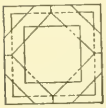


FIG. 7.

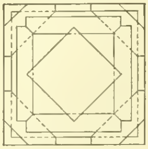


FIG. 8.

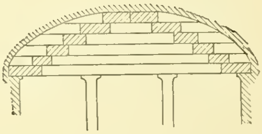


FIG. 9.

The Chinese have to use an entirely different material, which abounds in that country,—viz, a species of small pine which has the peculiarity of being soft and spongy inside, while the outer rims of wood just under the bark retain their strength and hardness. It is thus practically a wooden cylinder, good for direct compression and bending if left whole; but if sawed into planks, or "sticks" as we say, to form any kind of a trussed framing, would fall to pieces; like a built section of plates and angles with the

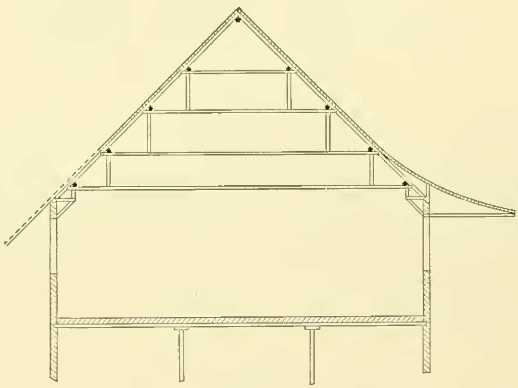


FIG. 10.

rivets left out. Therefore they make their upright supports of these small trunks, bracing them along the sides of the building with "sway knee-braces" of the same material, only smaller growth, and arrange their framing by means of a series of horizontal beams, each having its ends supported on that below by a short vertical strut of a sounder but rarer kind of wood. (Fig. 10.)

It is interesting by the way to notice how the requirements of

the Chinese climate are met by the peculiar outline of their roofs, which are concave. This is *not* copied from the tents of the wandering Tartars, which in fact were always domical, but they are so shaped for two reasons. During their rainy season such large quantities of water have to be carried off the roof that a low pitch would cause leaks, and therefore the part over the house must be steep. At another season of the year it is absolutely necessary that some shade be provided over the windows from the fierce, glaring sunshine. Now, if the roof were to run out over the windows far enough to furnish ample shade from the sun, it would come down so low as to also keep out the light and air (see dotted line at left of Fig. 10), and, consequently, John Chinaman curves up his eaves outside the walls, where a perfectly water-tight covering is not so necessary, thus forming the peculiar shaped roof with which we are familiar.

There is a method of roofing which should be mentioned before going into the growth of trussed structures,—viz, groining, which is essentially a combination of arches, meeting together, the lines of greatest pressure being marked by ribs, which in later ex-

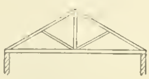


FIG. 11.

FIG. 12.

amples were often highly ornamented. Chapter houses of the old world cathedrals were generally covered in this way.

With the advancement of civilization there was a demand for more buildings, which were required to be erected in less time than had previously been the case, and a change from the old arch practice was necessary. To meet the new circumstances, the trussed roof was evolved, like the arch, from very simple elements. The commonest way of spanning openings up to about 12 feet had been by means of a single wooden beam. Wider spans suggested two beams sloping together; but instead of resisting the outward thrust so caused by means of buttresses outside the building, a horizontal tie-beam was thrown across, holding the two feet of the rafters together. (Fig. 12.)

When still greater spans were required the middle of each rafter was supported by means of struts, sloping in towards the bottom of a vertical post which ran from the apex to the middle of the tie-beam, so forming the well-known king-post truss. (Fig. 11.)

Further developments brought forth the queen-post truss, and others with more members to suit the span.

The larger use of timber framing followed the introduction of saw-mills. The earliest methods of cutting timber had been by wedge-splitting, which although it injured the fiber less was very slow and expensive. The Greeks invented the hand-saw, modeled either on a serpent's tongue or the backbone of a fish, and there is a literary allusion in fifth century writings that suggests crude saw-mills then; but not until the fifteenth century do we find reliable indications of wind saw-mills in Germany; and in England early in the seventeeth century, accompanied, as usual with all mechanical improvements, by the greatest opposition on the part of the workmen. Simultaneously we find the elaborately framed roofs of the perpendicular period.

There is a peculiar sort of roof-truss common in many old churches which made use of the hammer-beam. Essentially this truss is framed by merely putting a pair of brackets in the walls, and resting the truss on their ends. (Fig. 17.)

These were profusely carved and ornamented. There is a good example of the hammer-beam roof in the west wing of D. H. Holmes' store on Canal street in New Orleans.

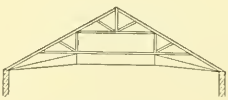


FIG. 13.

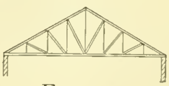


FIG. 14.

But all these older forms of trusses were made almost entirely of timber; with new methods of producing iron, and consequent diminution in its price, we see many changes. Keeping the same arrangement of members, those in tension were gradually replaced with iron; first the king-post (called the king-bolt when made of iron), and later the tie-beam, gave way to the iron horizontal tie-rod. It is curious to notice how closely the carpenters of those days kept to the memory of old timber trusses, and what abortions were often the result of its union with iron. Here is a roof-truss stretching across a hundred-foot span drill hall, in which we see the king-post at the top, lower down the queen-post, and some iron rods thrown in at the bottom. (Fig. 13.)

Perhaps the best type of this combination truss is the Princess, in which it will be noticed that the ties, which are iron, have a minimum length, an arrangement due to a desire to use as little as possible of a comparatively expensive material. (Fig. 14.)

The well-known Howe truss exhibits similar economy.

When the manufacture of cast iron became more reliable and better understood the compression members or struts were made

thereof; but as one of its properties is a great loss of strength when in long unbraced lengths, another change in the arrangement of members was required, which resulted in various forms of the Fink truss, which has short struts and long ties. (Fig. 15.)

This truss can be well used for bridge spans by turning down, and they tell how its introducer, an army officer in the Civil War, made a novel use of its properties to fool the enemy, who had been accustomed to bridges with two parallel chords. The Fink truss

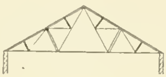


Fig. 15.

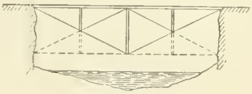


Fig. 16.

can be quickly built in an emergency, and when it was necessary to throw a bridge across water he used this type, but added superfluous members in the shape of a dummy bottom chord. (Fig. 16.)

The opposing forces, wishing to destroy the bridge, and supposing it to depend on the bottom chords, shot them away, when of course the essential members remaining intact, she stood solid, presumably to their great amazement.

Fig. 17.

This Fink truss is now well adapted to shipment, being riveted up at the shops in two (or for large spans, four) sections, which can be easily suited to railroad car capacities, and assembled in the field; whereas the older forms for larger trusses had either to be shipped with each member separate, or they were too high for transportation.

The struts in Fink trusses generally consisted of hollow cast iron tubes, attaching to special fittings at each end, and often orna-

mented at the middle with a shell casting. Such a connection is all right for a member always in compression; but when it became desirable to replace the building walls also with iron, wind strains often induced tension in some of these struts, for which the cast iron forms used were altogether unsuited. Then came the invention and improvement of new processes for making rolled sections, careful tests of properties and new tools, which combined to give sections strong both in compression and tension, of which the best modern roof frames are constructed. As a further example of the dependence upon shop work for our best practice in construction, it may be noted that until quite recently it was usual to make some allowance in the length of members, to be adjusted during erection with wedges, etc., a device which would throw out any careful and exact calculations.

The way in which iron and steel have entered into our roof construction is capable of much further illustration, having many points in common with modern bridge construction, as compared with older methods. In the first twenty pages of Theodore Cooper's book on American Railroad Bridges he shows how

Fig. 18.

wooden bridges were gradually improved with, and then replaced by, iron in its various forms, and there may be found many examples of this reconstruction period, which will also apply to large span roofs. From Mr. Cooper's very quaint list of old-time structures, and such other sources as have been available, the following may be of interest:

The first iron bridge in England was built about 150 years ago near Coalbrookdale over the Severn. It is a 100-foot span arch of cast iron. The 250-foot cast iron arch spans of the Southwark Bridge, London, built about 1810, are still in use. Cast iron was also used up to the middle of this century for railroad bridges, up to 40-foot spans, a girder section of this kind being used, but its liability to crack under impact and to fail in the tension flange rendered these unsatisfactory. (Fig. 18.) The first wrought iron to be rolled was by Cort, of Southampton, England, under patents of 1783, and during the first half of this century such wrought (or "malleable," as it was called) iron as was used, either for reinforcing tension flanges of cast iron, or later alone, had to be punched, beveled, bent, etc., either by hand or by means of a lever-fly, which machine consisted of a large weight acting at the end of a lever to

work the metal, something like a garrote. But in 1846-9 the hydrostatic press and steam riveter were introduced, whereby all shop work could be performed more economically and accurately, and access to these tools caused Robert Stephenson, William Fairbairn and Eaton Hodgkinson to decide on the use of wrought iron for the famous Britannia Bridge across Menai Straits. This structure has never been surpassed in many respects, and a few data may be of interest. It is called a tubular bridge, and is in theory constructed like an immense box girder, the train passing through the box. The top and bottom flanges consist of cells built up of plates, angles and tees, each cell being large enough for a workman to get inside to rivet up. In section this girder looks like Fig. 20.

Each tube is 472 feet long, two being placed side by side for the two railroad tracks, and the bridge consists of four spans resting on five masonry piers, 100 feet above water line. Each tube weighed over 1600 tons, and on account of the constant passage of vessels had to be constructed on trestling 100 feet high, on

Fig. 19.

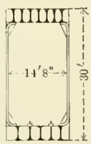


Fig. 20.

pontoons, and floated into place complete, the exactly correct elevation being secured by pumping water in or out of the pontoons. The first tube took two hours to get into place from the time it left its moorings. And all this in 1850, and over open sea water! (Fig. 19.)

But even these methods of working the material were comparatively crude and expensive (wrought iron being then worth nine cents per pound), and prevented its general use; and in the popularizing of iron for structural purposes we have to look to three causes, two of them entirely American,—viz, Eads' wonderful bridge at St. Louis, and the development of pneumatic tools. The other, Bessemer's process of converting pig iron directly into steel, is an English invention, but its fullest developments have occurred in this country.

Taking up the Eads' bridge first, 1868-74, one must note that the mills then rolled very few of what are now called "standard sections," each manufacturer turning out such shapes as appeared right in his own eyes. A glance at the catalogues of ten years ago shows that even then much of this isolation had not disap-

peared. It was necessary then for Mr. Eads not only to develop his general design, proportion the sizes of members and provide for his revolutionizing method of erection by the cantilever process, but, being unable to find the sections required on the market, he had also to design them, and indeed very largely the machinery for rolling them. After much discouragement he succeeded, and immediately there appeared the beginnings of that tendency to "standardize" which in its fullest developments enables one to telegraph to the shops an order for quite complicated structures in half a dozen lines, and know exactly the detail dimensions and arrangement of the material that will be shipped.

The next step was the Bessemer converter, which has enabled structural steel to be marketed at a price one-third of that obtaining for iron twenty years ago, and this for a material stronger by 25 per cent. Until quite recently Bessemer steel has been used more for buildings than for bridges, for a reason to be mentioned later; but its use in conjunction with hollow tile has made possible the twenty-six story buildings of the present time, combining cheapness, lightness and strength with the more convenient arrangement of interiors thereby made possible. Having then this material within reach, our engineers have developed its use along new lines to an unprecedented extent. The concentration of the loads in a building on the columns only has caused new departures in the way of foundations for soft localities, and has enabled the loftiest structures to be built right up against old and small ones, with minimum party wall damage and litigation.

But for a long time Bessemer steel has been debarred from railroad and other important bridges, etc., on account of the supposedly injurious effects of *punching* in disturbing the metal surrounding a hole. Engineers have specified that if used it should be drilled instead of punched, or reamed out, which has made its shop cost almost prohibitory. Just what the extent of this injury is has been a debated question; but the tool manufacturers have happily taken it out of the domain of practical questions by the series of pneumatic tools that have recently been put on the market, and by whose use holes can be sub-punched and reamed many at a time at a very low cost. These tools are also successfully used for shop and field riveting, beveling, caulking and many other purposes, insuring the highest class of workmanship. The effect of these improvements has been not only to give us better structures, but has caused a marked change in the practice of designing bridge spans. A few years ago a 100-foot span was always built on the pin-connected type. Now, such a span is preferably riveted

plate girders or lattice trusses, on account of rigidity; and with the larger use of the latter, theoretical points have arisen and been largely settled concerning the action of stresses in same and proper connections.

It may be of interest here to briefly compare American with what has been European (especially English) practice in bridge construction. In this country the entire working of the material is done at the shops, from details and templates very accurately prepared; and it often happens that half the members in a structure come from one place, and the balance 1000 miles away, and are never brought together until assembled in place at the site. So happily has this work been systematized, and so carefully are the working drawings checked and followed, that discrepancies need not be feared. In English shops the practice has been very largely to *cut and fit*, using fewer drawings and placing more de-

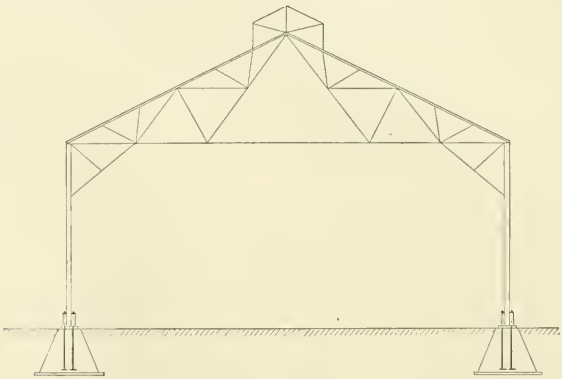


FIG. 21.

pendence on the workmen. During the construction of the Britannia Bridge, about 1850, and the Forth Bridge, as late as 1890, large shops were temporarily erected at the sites, where the various pieces were measured for and then worked piecemeal. In the case of a large bridge over the Indus in Hindustan, the London builder even went so far, in his fear of misfits, as to erect the entire structure in his yards before shipment, and then take down before sending away. An enormous expense! This comparison may throw a little light on the causes of America's recent success in competing for this class of work; for we secured the large Hawkesberry Bridge, Australia, against the world (the metal being manufactured and completely worked ready for erection in Pennsylvania), and we have lately been low bidders on several structures in Europe itself.

As an example of the effect of local conditions in bringing out well-known but little-used theory, the writer may briefly refer to a

point in his own New Orleans practice, in connection with light steel buildings, consisting of bents composed of two columns supporting clear-span trusses, with purlins and girts between, and lateral bracing. (Fig. 21.)

Such a bent is figured to resist the force of side winds by the action of the knee-braces, whose kick is withstood by the moment of resistance of the columns, and whose stresses are transmitted through the truss-members to the opposite side. The columns in other localities are customarily provided with small steel shoe plates, and short anchor bolts, say 15 inches long, and the lower end considered *hinged*. Now it is well known that a beam *fixed* at one end is much stiffer than if merely supported there; and a short consideration of our local conditions showed the possibility of this increased stability and economy. All our ground here is very soft and damp, and will carry only one-fourth the load that sounder soils elsewhere do. This means that the foundations for columns have to be unusually large and deep. Why could not these masses of masonry be utilized for "fixing" the feet of columns, thereby producing a point of contraflexure that would reduce the leverage of the wind-kick, and enable the sections of columns, knees and truss-members to be made lighter, and with increased stability?

The large anchor bolts (av. 2″ upset x 7.0″) and stiffener angles do not weigh as much as the saving in framing above, and the cast base-plates required for this construction are just what is needed to prevent the dampness rising to attack and rust the more susceptible steel above. This fixing the column bases also facilitates erection, and tends to prevent accidents during raising.

In conclusion attention should be called to the fact that since our earliest history there has been but little modification of the theories that govern a frame structure; and necessarily so, for they are simple and unchangeable. I count but three, and two of them were stated by Euclid and Archimedes over 2000 years ago so clearly that we still use their writings as text-books in our schools. These are:

1. The Triangle of Forces.
2. The Lever.
3. Ut Tensio Sic Vis.

If one can clearly follow out the workings of the first two, he can compute the stresses induced in the most complicated framing ever designed. A thorough understanding of the last is all that is necessary to properly proportion the various members to safely resist those stresses. The evolution of structural design has come about *not* so much from a deep searching into the abstruse mys-

teries of pure mathematics, as by the continuous and intelligent endeavor to meet the requirements of the thing in hand in countries widely remote, under changing conditions, and with materials of varying capacities.

We have seen how structures of such different types have been used, and why: the single huge stones in Egypt, because their shop or rather their field practice was to handle great masses; the stair-truss in China, due to the peculiarities of the timber there; the horizontal arch among the Hindus, because the radiating arch "never sleeps," and that would not suit a Hindu; the groined vault and heavily timbered roofs of Gothic church builders, those being the forms which would most readily adapt themselves to the interior decorative effects of which they were so fond, and which could then be cheaply sawed; and finally the steel roofs and bridges of our own time, which are the outcome of the experience and labor of our forefathers, the inventive genius of our ironmasters and the increased capabilities of our mechanical tools, combined with the demand for such mammoth structures as we see going up all around us.

THE MACHINERY OF VESSELS ON THE GREAT LAKES AND A SYNOPSIS OF RULES COMPILED BY THE GREAT LAKES REGISTER.

By John N. Coffin, Member of the Civil Engineers' Club of Cleveland.

[Read before the Club, September 13, 1898.*]

In 1896 the *Great Lakes Register* was organized to compile a complete classified register of all the shipping on the Great Lakes, the classification to be the basis for insurance rates for use by the marine underwriters.

The work of inspection and classification was started and carried on for some time under the sole direction of Captain F. D. Herriman, but later it was determined that a more thorough inspection of the machinery of the vessels than was at that time being made was necessary, and in February, 1897, our fellow-member, Mr. Walter Miller, was asked to take charge of this part of the work; and what is known as the Machinery Department of the Register was organized. As Mr. Miller has had full charge of this work I had hoped that he might be prevailed upon to favor us with a paper on the results, but he has requested that I write on the subject; and, as I have been connected with him throughout the entire work, I will, to the best of my ability, outline some of the results which have been developed.

As the classification of the vessels on the lakes was for the use of a combination of marine insurance underwriters, representing a number of insurance companies, it was necessary that the inspection and classified ratings should be made by absolutely impartial surveyors, so that each vessel should be given an unbiased and fair classification.

In the organization of this department our first idea was to secure a corps of thoroughly competent and impartial surveyors, and to formulate for their use rules which would insure thorough inspection and comprehensive reports, which would give us a complete description of all the machinery, both as to sizes of parts and as to their condition.

I will hand you one of our blank reports of survey, which, if you will examine it, will give you a much better idea of the completeness of the survey than I could by description. In addition

*Manuscript received October 15, 1898.—Secretary, Ass'n of Eng. Socs.

to the blank spaces for sizes and dimensions of parts of the machinery, you will note that blanks with headings for the description of the condition of the several principal parts of the machinery are shown. We have required answers in each of these blank spaces, thus assuring us that the surveyor had seen the parts and examined them, whether they were in perfect condition or not. The work of our surveyors has been very satisfactory, and their care in following out the minutest details has been of great assistance to us in our work of properly classifying the machinery. In this connection I would say that in several cases where vessels had been inspected by one surveyor they were afterward re-surveyed by another, thus giving us an opportunity of comparing their work; and in every such case this comparison has been very satisfactory.

Of more than 1300 vessels surveyed, we have found 1150 to be screw propellers and a trifle over 50 to be paddle, or side-wheel, propellers, the balance being schooners or tow barges equipped with boilers and steam pumps or with hoisting or steering machinery.

Of those fitted with screw propellers we have found that 960 had solid cast wheels, 6 of them being of bronze, 8 of steel and 946 of cast iron. One hundred and eighty-five had sectional wheels, one of them being bronze, 6 steel and 178 cast iron. Of the entire number, 1060 of these propeller wheels were fitted on the tail shafts with straight bore and key, while only 74 were fitted on a taper end with feather and nut, the latter arrangement being more modern practice and considered by most engineers to-day to be the preferable way of fitting propellers to the shafts.

Of the paddle wheels, we found 23 to be fitted with feathering floats and 29 to have solid floats.

NUMBER OF VESSELS BUILT IN EACH DECADE.

ENGINES.	1860 to 1869.	1870 to 1879.	1880 to 1889.	1890 to 1898.
H. P. non-condensing	40	93	185	93
" condensing	6	10	5	4
Steeple compound	22	62	89	39
F. & A. "	5	12	154	99
Triple expansion	..	..	67	147
Quadruple "	..	..	1	6
Walking beam	8	10	8	7
Inclined and horizontal	1	2	7	9
BOILERS.				
Fire box	18	97	392	224
Scotch	1	8	193	348
Water tube	..	1	...	35

Pressures.				
Below 50 lbs......	5	3	2	3
Above 50 lbs. and “ 75 “	4	19	23	10
“ 75 “ “ “ 100 “	5	59	122	29
“ 100 “ “ “ 125 “	1	25	318	173
“ 125 “ “ “ 150 “	..	3	52	184
“ 150 “ “ “ 175 “	..	1	70	161
“ 175 “ “ “ 200 “	..	..	..	19
“ 200 “ “ “ 225 “	..	1	1	12
225 lbs..................	..	..	..	2
250 “	..	..	..	12
265 “	..	..	..	2
300 “	..	..	..	1

Number of Vessels in each Rating, by Decades.

Ratings.	1860 to 1869.	1870 to 1879.	1880 to 1889.	1890 to 1898.
50	3	4	4	2
55	2	3	2	4
60	5	11	11	2
65	4	10	16	7
70	2	18	27	6
75	2	19	58	23
80	1	25	78	40
85	1	18	88	54
90	..	9	138	119
95	..	5	87	124
100	..	..	62	223

Referring to the table of engines, you will note some very interesting data relative to the advent and growth of the different types of engines.

For instance, you will note that the high pressure non-condensing engine, our earlier type, held the supremacy in numbers up to the end of the decade 1880 to 1890. This is accounted for in some degree by the fact that during the latter part of this period many small boats and tugs were built. The high pressure condensing engine cuts very little figure on the lakes, there being a total of only 25 in existence there.

The steeple compound engine had an early start, 22 of them now in existence having been built earlier than 1870, 62 during the next ten years and 89 during the period from 1880 to 1890. This type then gave place to the advent of the fore-and-aft compound and triple-expansion types.

Of the fore-and-aft compound type we have five engines built earlier than 1870. This type also reached the height of its popularity during the years 1880 to 1890, and then gave way rapidly to the triple-expansion engine, which makes its first appearance during this term with 67 examples, and which has held its supremacy with 147 engines built since 1890.

The first quadruple-expansion engine was built in 1889.

Since that date there have been 6 vessels equipped with this type of engine, and there are several of this type now under construction.

Of the paddle-wheel boats, you will note that 33 engines are of the common and well-known walking-beam type, while 19 are either horizontal or inclined engines.

It is also interesting to note the changes which have taken place in the types of boilers. The marine fire-box boiler is the most common type, though it has lost its prestige, the Scotch boiler having rapidly displaced it of late years. Seven hundred and thirty-one boilers of this type are in use to-day, 18 of them having been built earlier than 1870, 97 of them between 1870 and 1880, 392 between 1880 and 1890 and only 224 since 1890.

The Scotch type of boiler has one example built earlier than 1870, 8 between that and 1880, 193 between 1880 and 1890 and 348 built since 1890, a very rapid increase during the last seven years.

The marine water-tube boiler is of more recent date, only one having been built earlier than 1880. There are none of this type now on the lakes built between 1880 and 1890, but there are 35 vessels, built since 1890, equipped with this type of boiler; and there are several vessels now under construction which are to be equipped with this type of boiler, and it is the opinion of many engineers that the water-tube boiler is the coming boiler for marine use.

It is also interesting to note the gradual increase in pressures in boilers built during these several periods.

In those built earlier than 1870 100 pounds per square inch is the highest pressure, and there is only one boiler of this period carrying as high as 100 pounds and only one carrying 90 pounds, most of the boilers built during this period carrying pressures from 40 to 55 pounds.

Most of the boilers built between 1870 and 1880 carry either 80, 90 or 100 pounds pressure, though there are a few, built during this period, carrying considerable higher pressure and one carrying as high as 200 pounds.

During the period of 1880 to 1890 276 boilers were built which carry 100 pounds pressure or less, and 318 which carry more than 100 pounds; but there is only one boiler built during this period carrying as high as 200 pounds, 29 carrying 160 pounds, 39 carrying 150 pounds and the balance ranging from that down to 100 pounds pressure.

Since 1890 the tendency has been to a considerable increase of pressure. Only 91 of the boilers built during this period carry as low as 100 pounds, while 517 carry pressures higher than 100

pounds. Of this number 75 carry 120 pounds, 82 carry 125 pounds, 45 carry 150 pounds, 83 carry 160 pounds, and from that on up to 300 pounds, there being one boiler carrying this highest pressure, 2 boilers carrying 265 pounds pressure and 12 boilers carrying 250 pounds pressure.

In our survey of boilers it was not deemed necessary to make hydrostatic tests, as every boiler has to pass a Government inspection and test each year before the vessel is licensed to sail. Our survey has, therefore, been only for condition and to ascertain the care that the boilers receive. In this connection we have found 295 boilers to be patched inside, and 264 to have patches on the outside. Eighty-two boilers are shown to be poorly fastened to the hulls of the vessels; 139 boilers are without stop valves between them and the throttle valves; there are 191 cases where the slip-joints in the main steam pipes are not protected with safety guard bolts; there are 134 cases where there are no cocks between the feed check valves and the boilers, and there are 165 cases where the feed check valves are only common pipe checks.

Referring back to the subject of engines, it was rather surprising to find the lack of uniformity of proportion of parts of these machines. There seem to have been no hard and fast rules for the construction of engines on the lakes, and each builder has followed his own ideas to a greater or less degree in the proportion of the several parts of the engines he built, as well as in its special design. In the item of crank shafts we have found that about 400 were of the solid forged type, 17 of these being of steel and 383 of wrought iron. Seven hundred and eighty were built-up shafts, of which 23 were of interchangeable sections, 13 of them being of steel and the remainder of wrought iron. Of the total number, 354 were found to be light in section, according to the Lloyds's rules for determining the size of crank shafts.

We also found 106 cases where the intermediate shafts were light of section, and 387 cases where the propeller shafts were light of section, by these same rules; and we found 48 cases where the shaft couplings were reinforced, either on account of breakages or because of developed weakness.

There were also found 296 cases where the thrust bearings were insufficient to properly relieve the crank shafts from fore-and-aft strains. A perhaps more serious defect, from the insurer's standpoint, was found in the light cross-head connections, 446 cases occurring where cross-head keys were too light and 54 cases where the nuts fastening piston rods into cross-heads were small. This is a serious defect, and several recent accidents have occurred from

light construction in these parts. A point which seems to have been very sparingly covered by authorities on engine design, and yet which seems one of vital importance to us, is the bolting of cylinders to columns, of columns to bed plates and of bed plates to seatings in marine engines. The strain to which each of these parts is subjected being a direct strain, the necessary strength of these parts is easily found by computation based on the steam pressure and the size of cylinders. In these parts we have found 340 cases where the cylinders were too lightly fastened to the columns, 68 cases where the columns were insufficiently secured to the bed plates and 64 cases where the bed plates were not sufficiently bolted to their seatings.

We have also found several cases where the fastening at the ends of connecting rods is too light for safety.

In most of the cases where light cross-head connections and insufficient bolting of cylinders to columns, columns to bed plate and bed plate to seatings were found, the condition has occurred through the replacing of old, worn-out boilers by new boilers of higher pressure without increasing the parts of the engines; but we have also found several cases of recent construction where these parts were originally made entirely too light for safety.

The use of relief valves on steam cylinders has been appreciated only since the compound engines and higher steam pressures have become common, but it has become a matter of vital consideration. We have found over 650 cases where the cylinders were not so safeguarded. Many of these, however, were non-condensing engines, carrying only moderate steam pressures, but we have found 58 cases where cylinders were cracked and patched and in most of which the damage might have been avoided had there been proper reliefs.

In the cast iron parts of engines, such as bed plates, columns and channel plates, the builders on the lakes have not been sparing in the use of metal, though we have found 66 cracked bed plates, 63 broken columns and 5 cracked channel plates. Still, in almost all of these cases the breakages have occurred from carelessness on the part of the engineers in allowing water to become entrapped and freeze in winter when the boats were tied up, rather than from light construction.

We have also found 148 cases where the stern logs or pipes or stern bearings were defective. In most of these cases the defect is from decayed wood, caused by leakage, or from insufficient fastenings of the stern pipes in the stern logs.

Our inspection of pumps, piping and connections has been

especially rigid, and, while we have found very few cases of broken pumps, we have found many cases where the piping and sea connections were defective. There are 762 vessels on the lakes in which the sea connections are not fitted with non-return valves, so that water could not, either by accident or intention, be run into the vessel. This is a fault the seriousness of which has been especially illustrated during the past winter, when a great number of vessels were loaded with grain in the fall and used for storage during the winter at Chicago. In a great many of these vessels damaged grain was found in the spring, from the leakage through the sea connections, which if they had been fitted with non-return valves would not have occurred.

There are 153 vessels in which steam and water pipes pass through the coal bunkers without proper protection, and there are 92 vessels on which the fire apparatus is either out of order or insufficient.

Our survey of the electrical equipments has as yet been rather superficial, and has really amounted to only the listing of boats having such equipments; but we are now starting on a very much fuller and more rigid inspection of these equipments. We have found 312 vessels equipped with electric lighting apparatus. A number of these equipments are rather crude, and the installation and wiring far from satisfactory; and there have been a number of cases of damage to cargoes and vessels from fire started through defective insulation.

We are, of course, not at liberty to say very much regarding the ratings whicn have been placed on the different vessels on the lakes, but there are some points in regard to the ratings on machinery which are of interest and which we may divulge.

It was not our intention to use age as a factor in the rating placed on machinery, but to base the rate entirely on the construction of the machinery and its condition of preservation. From a table compiled from the ratings placed on the more than 1300 vessels, however, the fact is shown that age does cut a considerable figure in connection with the condition.

The highest classification given to any vessel built previously to our rules compiled for future construction is 100, and we rate from that down to 50 by points of five.

It is interesting to note that the boats on which the machinery is rated as low as 50 were built during the following periods: Three between 1860 and 1870; 4 between 1870 and 1880; 4 between 1880 and 1890, and 2 since 1890.

The rating of 55 is distributed about the same, although there are four boats built since 1890 rated as low as 55. This low rating on recently built boats is accounted for by light and faulty construction, and from the fact of their being very poorly cared for.

The highest rating given to any boat built earlier than 1870 is 85. The majority of those built between 1870 and 1880 rate from 70 to 90, and the majority of those built between 1880 and 1890 rate from 75 to 95, although there are 62 built during this period rating as high as 100. Most of the boats rating 90, 95 and 100 have been built since 1890.

In compiling rules for future construction it has not been our intention to create anything particularly new or to deviate widely from the rules adopted and maintained by the older classification societies, such as London Lloyds, British Corporations and Bureau Veritas, but it has been our aim rather to carefully select and adapt such rules as may have a special bearing on the peculiar requirements of the practice on the Great Lakes. In this respect we have taken the rules of the older societies as our basis, simplifying them where we deemed simplification possible and adding to them such items as seemed advisable to cover these special requirements, basing our alterations and additions on the data gathered from our survey of more than 1300 vessels now running on the lakes. These data showed us beyond question whether the rules which we took as our basis were sufficient or were more rigid than the requirements demanded.

We have divided the rules into four separate heads or sections,—viz, Engines, Pumps, Piping and Connections, Boilers and Electrical Equipment.

Under the first heading, Engines, we have deviated very little from the established rules of the older societies, for they cover very fully all requirements met with in lake practice. We have, however, where we could, simplified the formulæ for determining the sizes of the several parts, and have recommended, though we have not insisted upon, such items of more modern practice as the fitting of the propeller wheels on a taper tail shaft with feather and nut, and the use of taper and shoulder connections of piston rods in cross-heads; and have covered very much more fully than the older societies have the items of fastening of cylinders to columns, columns to bed plate and bed plate to seatings. In connection with these latter items we have compiled very simple formulæ for determining the strength of these fastenings, and have published, in connection with these formulæ, tables showing the

strength of studs and bolts of different sizes, such as are used in making these fastenings.

In these rules we have also covered very carefully the points of determining the minimum size of crank, intermediate and propeller shafts; of the thrust surface of thrust bearings, so as to entirely relieve the cranks of the engines from fore-and-aft strains; the fastening of piston rods in cross-heads, either by key or by nuts; the thickness and strength of cylinder walls and heads, and the proper staying of cylinder heads by ribs; and we have also called particular attention to the fact that cylinders and receiver chests must be fitted with relief valves of sufficient size to safeguard them from undue strain.

Under the heading "Pumps, Piping and Connections" we have covered those points, as to the necessary pumps, that are required by the older societies, and as to the strength of piping for different purposes; and, in addition to these points, covered by the older societies, we have included such items as—

First, that no pipes are to be carried through the coal bunkers without being properly protected.

Second, that in all steam pipes provision must be made to permit expansion and contraction to take place without unduly straining the pipes, and that all stuffing-box expansion-joints must be fitted with safety guard-bolts to prevent the end of the pipe from being forced out of the joint.

Third, that in order to have at all times full control of valves and pipes connecting engines, boilers or ballast tanks with the sea, they must in all cases be so arranged that water cannot, either by accident or by intention, be run into the vessel; and that, in cases where pipes are led or so placed that water could run into the vessel from either sea or boiler, they must be fitted with non-return valves.

Fourth, that all inlets or outlets in the side of the vessel near to, at or below the deep load line must be fitted with cocks or valves, fitted close to the side of the vessel. We have also insisted that all exhaust pipes from windlass, capstan, deck and steering engines, and from all auxiliary engines and pumps, must not be led through the vessel's side, but must be led to the main waste steam pipe, which should in all cases have a drain pipe led to the engine-room bilge or hot-well.

Under the heading of Boilers our rules have, of necessity, been made to comply as closely as possible with the rules laid down by the United States Board of Supervising Inspectors. We have, however, tried to simplify as much as possible these rules and

the formulæ for determining strength of the parts, and have added only such rules as we deemed necessary for safety from the insurer's standpoint.

The rules for boilers, of course, cover only the common types, such as firebox, Scotch and vertical cylindrical boilers; as, with the marine water-tube type of boilers, each maker has a special design of his own and the boilers having individual features, it was impossible to lay down hard-and-fast rules covering this type. To cover all such cases we have inserted the clause, "All other types of boilers than those referred to must be submitted to the board for approval." In this way we give the Engineering Department of the Register the opportunity of inspection and approval of the plans of all odd types of boilers before permitting them to be installed in modern vessels looking for our highest classification.

Under the heading of Electrical Equipment we have adopted almost verbatim the rules laid down by the National Board of Underwriters for the installation of wiring and apparatus for electric light and power, adding to these rules only such features as were particularly applicable to marine practice, one of the most important of which is the rule that all lamps in cargo holds must be on a separate circuit run direct from the switchboard, and with a pilot lamp on the switchboard to detect current on this circuit when the cargo hold is closed.

In this connection I might say that a number of losses to the insurance companies have occurred recently from damage to grain cargoes from faulty wiring and connections in the cargo holds, the lamps in cargo holds of many of the vessels now electrically lighted being simply branch lights, taken from the main circuits of the equipment.

In cases where this method of equipment is used the only way of switching off the lights in the cargo holds is by the local switches at the lamps, and after the cargo hold has been filled and closed it is impossible to tell, either from the engine-room or from the decks, whether or not the lights in the cargo hold are burning when the current is on the main circuit, and it is consequently impossible to tell whether or not there is any danger of fire in the cargo. Our other rules for electrical equipment are those common to all societies governing the apparatus and installation of electrical equipment for lighting and power.

In closing, I wish to say that this work, both in the inspection of vessels now on the lakes and in the compiling of the rules for future construction, has been exceedingly interesting and instructive, and it was a great pleasure as well as benefit to me to be

associated in it with such a man as Mr. Miller, who is not only so thoroughly competent to undertake such work but is also so conversant with the practice of construction of marine engines and boilers on the lakes for the past twenty years.

DISCUSSION.

Mr. Jos. R. Oldham.—About thirty years ago, when I was Engineer of the Bureau Veritas, the first triple-expansion engine was being built. You understand, I suppose, that the classification of a ship merely means giving her a character. Mr. Coffin described very minutely the examination of all the vessels on the lakes, but I would ask him whether good results were obtained from these examinations, for I did not hear him say what improvements resulted from them. It is a serious thing that within the past two years no less than six vessels have had their engines blown to atoms, and I should very much like to know whether Mr. Coffin or Mr. Miller can tell us anything about the cause of these accidents.

The suggestion as to a stop-valve between the engine and the boiler is a very wise one. Last week I was on a vessel where the captain wanted to fill one tank. The bottom of one was leaking. The bilge pump was working, and one of his tanks could not be filled because the pump was drawing water from another. Filling pipes should be quite distinct from emptying pipes. I do not know that I need say anything more, except to compliment Mr. Coffin very much on his paper. If any one wants a copy of my book, entitled "The Great Lakes Register of Shipping," I shall be pleased to present him with one.

Mr. Walter Miller.—It would be out of place for me to discuss Mr. Coffin's paper, but, owing to Mr. Oldham's remarks, I want to touch on this question of break-downs which is attracting so much attention.

Those who are interested in such matters seem very anxious to discover the cause of the trouble. These break-downs are very mysterious and unexplainable. Of course, we all know about water in steam pipes, etc., but just how it acts to cause the destruction of the pipes it is difficult to say. In the case of the steamer "Maniton," in which one of the two bolts in the cross-head broke, each bolt had material enough to do the work alone, provided it had the proper connection, but this bolt broke without any apparent cause. In the case of the "City of Chicago," the connecting-rod strap broke at the junction of the two brasses; and when the strap parted there was not more than 1-10 of the section

holding, as there was only a thin section of material left around the outside of the strap, and the balance of the section was gone. A fragment which remained was stretched like a piece of rubber, and the other side of the strap was bent at an acute angle without the least sign of fracture. In the case of the "Iron Age" the connecting-rod strap broke at the junction of the two brasses, the same as in the case of the "City of Chicago." In the case of the "State of Ohio" the connecting-rod broke at about 3 feet from the lower end of the rod where a band was clamped on it, to which the braces which steady the rod were attached.

In all of the above-described cases the material was good, as could be seen by the character of the break; and it had ample section to do the work, yet it failed. Just why these parts failed it is difficult for any one to tell, but such breaks are commonly attributed to crystallization.

THE "ECONOMETER."

By H. M. Kebby, Member of the Technical Society of the Pacific Coast.

[Read before the Society, October 7, 1898.*]

The process of making steam presents two problems: first, the production of heat from a given combustible; second, the utilization of the heat obtained; and it is regarding the first of these problems that we submit facts for consideration.

In every pound of coal a definite amount of heat is contained, varying as the quality of the coal varies; and the process of liberating this heat is known as combustion. To liberate all of the heat it is necessary to have perfect combustion, and the elements requisite for obtaining that result are unvarying.

In order to produce combustion, carbon, the vital element in the coal, must unite with oxygen, which it does in certain unvarying proportions. In the first stage of combustion one part of carbon unites with one part of oxygen, forming a combustible gas, known as carbon monoxide, and in this process about one-fourth of the heat is liberated. In the second stage the carbon monoxide absorbs another part of oxygen, forming a gas known as carbon dioxide, or carbonic acid, and in this process the rest of the heat is liberated. As there is 21 per cent. of oxygen in the air that is conveyed to the carbon, it is easily seen that perfect combustion would produce 21 per cent. of carbonic acid, since all of the oxygen would unite with all of the carbon and every heat unit contained in the coal would be liberated.

For many reasons, it is next to impossible to obtain perfect combustion in any steam boiler furnace, but it is possible to obtain and maintain good combustion with proper firing and correct manipulation of the draft and dampers. It is easy to see that the only test to be applied is that of determining the amount of carbonic acid present in the escaping gases, and that the value received from the burning of all coal is in exact proportion to the percentage of this gas. Chemistry has determined these values, so that when the per cent. of carbonic acid is known the value received from the burning of any coal can be ascertained; we annex a table showing these relative values, from which it is apparent that the difference between burning coal properly and improperly means many tons a year to a steam plant of any size.

*Manuscript received October 13, 1898.—Secretary, Ass'n of Eng. Socs.

In Europe, where coal economy has received the greatest attention, it has long been the custom to provide engineers with chemical apparatus, by which the percentage of carbonic acid could be determined at intervals. This determination, though irregular, proved of the greatest value, and led to the invention of the Econometer, which indicates continuously the exact percentage of carbonic acid contained in the escaping products of combustion. The value of having a continuous indication, rather than one obtained at infrequent intervals, can hardly be overestimated, for a constant guide to firing is thus obtained.

Carbonic acid is 50 per cent. heavier than air, and thus the greater the percentage contained in any given volume of flue gases the greater the weight of that volume. In the Econometer a sample of the escaping gases from the boiler is drawn continuously through a balance scale suspended in air, and the variations in weight that are produced by the different states of combustion are made to record the percentage of carbonic acid. The weight of this gas varies with the temperature, but in the Econometer the sample to be weighed and the air in which the weighing is done assume the temperature of the room, so that the proportion remains exact.

It is plainly evident that for each pound of coal a fixed amount of air is necessary for combustion, varying as the percentage of carbon varies in the different coals. For a pound of average quality about 125 cubic feet of air is necessary, and it is the inability to convey the precise amount to the furnace that prevents our obtaining and maintaining perfect combustion.

If too little air is admitted combustion becomes imperfect, because the carbon monoxide cannot find the necessary oxygen to complete its transformation into carbon dioxide; and this is the most wasteful condition of firing, for the largest part of the heat is given off in the second stage of combustion. This case is seldom met with in practice, for most boiler furnaces are supplied with too much air. Then the combustion is poor because there is a large amount of air passing through the fire, the oxygen of which cannot be consumed. This surplus air must be heated to the same temperature as the escaping gases, thereby absorbing the heat already generated, which should pass into the water contained in the boiler. The loss here may be compared with that occasioned by pumping cold water into a boiler, instead of heating it to the boiling-point by exhaust steam, as is usually done.

This loss of fuel shown in the annexed table, as calculated and proved, can be caused in a variety of ways, and is to be sought for

in all of the accessories of the furnace. It may result from an excessive or defective draft; from faulty grates or wrong proportion of grate surface; there may be defects in the boiler setting or in the fire or ash-pit doors. The proper thickness of fire, varying with the many different conditions surrounding all steam plants, must be determined.

By first obtaining the percentage of carbonic acid in the gases produced with ordinary firing, and then experimenting with the boiler equipped with the Econometer, any fireman can soon ascertain the proper thickness of fire and draft necessary to insure good combustion. If, with a high percentage of carbonic acid, the gauges show too much steam, a case often experienced in practice, it is evident that the grate surface should be reduced, which can be done by bricking up at the back end of the ash pit.

A very common source of waste is the formation of holes in the fuel on the grate, and the Econometer is a never-failing indicator of the presence of such holes. By drawing samples of gas from the entrance and exit of the flues, and comparing the percentage of carbonic acid, any existing defects in the setting and brickwork will be discovered.

The following table shows the loss of heat and fuel, with from 2 to 15 per cent. of carbonic acid (CO_2) in the combustion gases.

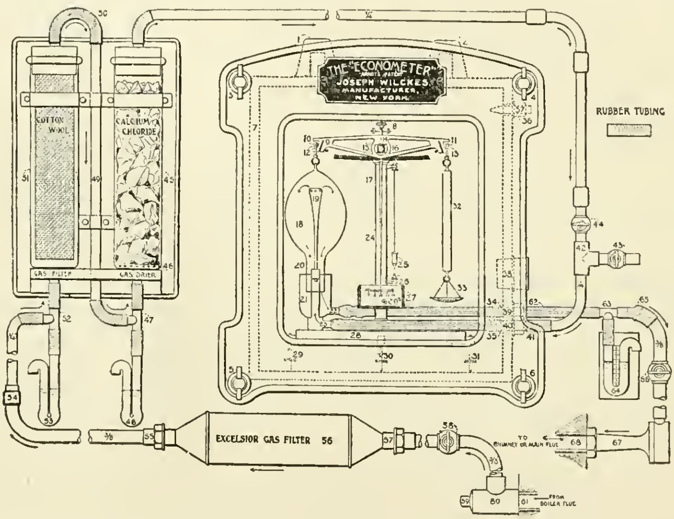
The proportion between the amount of air actually used and the theoretical amount required is, in the case of coal (according to Bunte), $\frac{18.9}{K}$, K being the per cent. of carbonic acid in the gases.

FOR COAL OF MEDIUM QUALITY.

If the "Econometer" shows	2	3	4	5	6	7	8	Per cent. carbonic acid.
Then the quantity of air passing through the flues is	9.5	6.3	4.7	3.8	3.2	2.7	2.4	Times the theoretical requirements.
With a surplus of air of 30% or about 166 Cu. Ft. of necessary air per lb. of fuel, there will still be a further excess of about	1977.6	1212.5	960.5	606.3	538.8	395.5	310.8	Cu. Ft. of superfluous air heated to a temperature of usually 518° Fahrenheit.
And the loss of fuel at 518° Fah amounts to	90	60	45	36	30	26	23	Per cent.
If the "Econometer" shows	9	10	11	12	13	14	15	Per cent. carbonic acid.
Then the quantity of air passing through the flues is	2.1	1.9	1.7	1.6	1.5	1.4	1.3	Times the theoretical requirements.
With a surplus of air of 30% or about 166 Cu. Ft. of necessary air per lb. of fuel, there will still be a further excess of about	197.8	169.5	113	84.8	56.5	28.3	0.0	Cu. Ft. of superfluous air heated to a temperature of usually 518° Fahrenheit.
And the loss of fuel at 518° Fah amounts to	20	18	16	15	14	13	12	Per cent.

One glance at this table shows conclusively the immense practical advantage of the Econometer, and will convince every expert and coal consumer that this apparatus is a most important equipment of every steam boiler.

Referring to the cut, the gas is taken from the combustion chamber of the boiler, not less than 9 feet back of the bridge wall, by the connection marked "61." It then passes through the filter marked "56," which is a brass filter case packed with excelsior; this takes the coarse particles of soot from the gas. From this filter the gas passes to the filter marked 51, which is a glass tube of about 3 inches in diameter, containing a wire gauze tube suspended so that there is a clear space all around between it and the



wall of the glass tube. This gauze tube is packed with cotton, wool, and the passage of the gas through it removes the remaining particles of dirt. The gas then passes to the filter marked 45, which is a glass tube filled with calcium chloride; the passage of the gas around the lumps of chloride frees it from moisture, which drops to the siphon marked 48, and overflows when the siphon fills up. The gas, now thoroughly cleaned and dried, passes to the weighing globe marked 18 through the $\frac{1}{4}$-inch pipe and up through the perforated glass tube marked 19. From the weighing globe the gas passes out through the cup-shaped vessel marked 21, and the rubber tube to the $\frac{3}{8}$-inch pipe connection to the stack, or to the main flue, beyond the damper. This $\frac{3}{8}$-inch pipe is connected to the stack through a brass aspirator marked 67, the purpose of the aspirator being to create a draught slightly in excess

of the flue draft, thus insuring a constant flow of gases through the instrument. Between the chloride filter and the weighing globe is shown a tee 42 and stopcock 43, which are so placed that by shutting off stopcock 44 and opening 43 the gases in the instrument will be drawn off and atmospheric air take their place. This will avoid the discoloring effect the gases would have on the glass should they not be withdrawn when instrument is out of use, and also test the balance, which should come to zero when only air is present. The instrument is calibrated by changing the amount of iron filings on weight pan 33 by means of a magnetic needle through the opening in the box marked 38, which is closed by a rubber plug when not in use. The scale for weighing the gases is enclosed in a cast iron box with glass front, which is airtight with the exception of a small glass tube 37, packed with cotton wool, to allow a small quantity of air to fill the box, thus keeping the gases in their proper channel. Between the box and the stack is a draft gauge 64. By turning off the stopcock 66 the stack draft will be shown; then by opening this cock slowly until the draft is increased about $\frac{1}{8}$ of an inch by the aspirator, the gases will flow through the instrument with the proper speed. Should the gases pass too quickly, they will impinge on the weighing globe and give an unsteady motion to the scale balance, thus defeating the primary object, which is to show the percentage of CO_2 on the vernier by means of the pointer attached to the balance.

Below is the report of the Franklin Institute of Pennsylvania on this instrument. The report gives a good description of the apparatus and its working:

REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS, FRANKLIN INSTITUTE, INVESTIGATING THE INVENTION OF MAX ARNDT, OF AIX-LA-CHAPELLE, GERMANY. NO. 1973.

HALL OF THE FRANKLIN INSTITUTE.

PHILADELPHIA, September 1, 1897.

The Franklin Institute, of the State of Pennsylvania, for the promotion of the mechanic arts, acting through its Committee on Science and the Arts, investigating the merits of Arndt's Econometer, reports as follows:

The sub-committee appointed to investigate the operation of an instrument for the measurement of carbonic acid gas (CO_2) escaping in the flow of the products of combustion from a steam boiler furnace have performed the duty assigned to them, and beg to report as follows:

This instrument is known under trade name of Econometer, and is the invention of Max Arndt, of Aix-la-Chapelle, Germany, by whom it was patented in the United States October 16, 1894.

Through Mr. Joseph Wilckes, of New York city, the inventor's American representative, a request has been presented to this institute for an

examination into the merits of the instrument, for the purpose indicated above.

The apparatus consists of a balance beam, carrying at one end a gas vessel provided with a neck open at the bottom, a gas delivery pipe projecting upward into this vessel being fixed and supported in it in such a way that upon the oscillation of the balance beam the gas vessel may move freely up and down without coming in contact with the upward projecting pipe through which the gas flows into the vessel.

The gas vessel is balanced by a compensating vessel suspended from the opposite end of the beam, also open at the bottom, and equivalent to the gas vessel in its capacity in conjunction with small weights placed on a pan under the compensating vessel, that the pointer of the beam shall move to zero on the scale when atmospheric air is drawn through the apparatus.

The gas vessel being open at the bottom, so that the pressure within it is always the same as that without, fluctuations of pressure and barometrical readings have not to be considered in the use of the apparatus; likewise fluctuations of temperature do not affect its action, because the gases passing slowly through the apparatus quickly take the temperature prevailing in the narrow gas passage.

The fluctuations which take place in the density of the gases round the fixed pipe in the gas vessel cause up-and-down motions in the latter vessel, which are shown by the pointer on the scale. This pointer is rigidly fixed to the beam so as to follow the movements of the gas balance; it oscillates in front of a divided plate or scale, indicating units of weight by the distance between its dividing lines; or these distances shall, in conjunction with the pointer, indicate a particular percentage volume of a particular kind of gas in a gaseous mixture. For example, the instrument placed at the disposal of this committee had divisions on its scale for indicating the percentage volume of carbonic acid gas, for the purpose of ascertaining the percentage of such gas escaping in the products of combustion from a steam boiler furnace.

Two tubular orifices are provided, one for the inlet and the other for the outlet of the gases, the former connecting by a flexible tube with the vertical fixed pipe in the gas vessel and the latter by a flexible tube with the cup-shaped vessel situated below the gas vessel. The source of the gas supply is placed in communication with inlet leading to the gas vessel, and a suction apparatus of any suitable kind in communication with outlet from the cup vessel under the gas vessel. A portion of the air present in the casing is first drawn off; that is to say, the air is exhausted by suction to so much of a vacuum as corresponds to the strength of the suction at the cup vessel under the gas vessel. This rarefaction being obtained, the gas to be weighed passes into the gas vessel, filling it, and then out of this vessel into cup vessel below.

The gas balance is inclosed in a casing with a glass front for the purpose of observation; this casing is provided with an aperture closable by a plug, upon the removal of which the weights may be adjusted as required. Further, at the top of the casing there is an aperture filled with cotton wool for the gradual and continuous admission of atmospheric air thereto. The balance is, therefore, located in a nearly air-tight chamber, with its several parts so arranged that when the gases to be weighed flow through a vessel

forming part of the balance it may operate without resistance and with great sensitiveness.

The determination of the percentage volume of a particular kind of gas contained in a gaseous mixture is only practicable by means of the apparatus when the specific gravity of the gas sought for is different from the specific gravities of the other gases preponderating in the gaseous mixture, but such other gases may be of like specific gravity among themselves. This, for instance, is the case with respect to the smoke gases of steam-generator furnaces, which gases are made up of oxygen, nitrogen, carbonic oxide and carbonic acid. Of these, the first three are of nearly the same specific gravity, approximating that of atmospheric air $= 1$. On the other hand, the specific gravity of carbonic acid $= 1.52$, and is therefore about one-half heavier than atmospheric air; and a smoke gas mixture must consequently be heavier the greater its contents of carbonic acid. With perfect combustion of the carbon contained in the fuel and with the air of combustion measured in a theoretically accurate manner, the carbonic acid of the smoke gases amounts to about 20 per cent. of the total volume; but it is less than this when the air of combustion is supplied in a larger quantity. If now the zero line of the scale has such a position that it coincides with the pointer when only atmospheric air is present in the gas vessel; if, further, the end line or division of the scale has such a position that it coincides with the pointer when atmospheric air mixed with carbonic acid to the extent of 20 per cent. of the total volume, as determined by a chemical analysis, is drawn through the gas vessels; and if, further, the scale has twenty corresponding divisions, then the movement of the pointer from one division to another will correspond to the difference in the weight of the gaseous mixture in proportion to the percentage volume of carbonic acid; and, accordingly, in the practical use of the apparatus, that is to say, when smoke gases are being conducted through the gas balance, the contents of carbonic acid, as indicated by the pointer in a sufficiently accurate manner for practical purposes, may at any time be read off from the scale direct. If, for instance, the pointer points to the division line marked 12 on the scale, this would indicate that the smoke gases drawn through the vessel contain 12 per cent. in volume of carbonic acid; that is to say, the volume of the latter would amount to 12 per cent. of the whole volume of the smoke gas mixture.

If the smoke gases of a steam-generator furnace when passing to the chimney have a temperature of 270° C. (or 518° F.), and 12 per cent. of their total volume consists of carbonic acid, the loss of heat amounts only to about 15 per cent.; but if at the same temperature the carbonic acid contents amount, for example, to only 4 per cent. of the volume of the waste gases this would show a loss of heat of about 45 per cent., due in a great measure to the heating of an excessive quantity of air for the combustion of the fuel. Hence it results that the gas balance herein described is of great importance as a controlling apparatus for steam-generator and other furnaces, and also for obtaining the specific gravity of other gaseous mixtures by direct weighing.

A practical test of this instrument was made by the investigating committee at the Baldwin Locomotive Works, in this city, with the results given in the annexed table. The boiler furnace from which the supply of gas was taken was one in which anthracite coal was used, the boiler was of

the Babcock & Wilcox manufacture, and its furnace setting was in no respect different from their ordinary practice. The gas analysis was by Prof. Harry F. Keller, Ph.D., of this city; each analysis was made immediately upon the withdrawal of the samples and at the place where the other tests were being conducted.

These comparative tests satisfied the investigating committee as to the substantial accuracy of this instrument. The recorded variations given in the annexed tables show discrepancies so trifling that if the Econometer were used in the management of steam boiler furnace fires no considerable loss would occur by reason of the difference between the Econometer reading and the chemical analysis. A saving of fuel would result because of a better and more intelligent management of fire and dampers, allowing less surplus of air to pass through the furnace than would ordinarily be the case.

The Econometer works continuously, and shows automatically the percentage of carbonic acid in the gases, thus enabling the fireman to see at all times the more or less favorable conditions of combustion.

The claims made for this instrument have, in the opinion of the investigating committee, been fully substantiated in its presence, and the Franklin Institute therefore awards the Elliot-Cresson Medal to Max Arndt, of Aix-la-Chapelle, Germany.

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, October 6, 1897.

John Birkinbine, *President.*
Wm. H. Wahl, *Secretary*

Countersigned by James Christie,
Chairman of the Committee on Sciences and the Arts.

DISCUSSION.

President Molera.—At the Beale street wharf an instrument was put on in connection with a system of smoke burning, and it showed from 6 to 9 per cent. of carbonic acid. By regulating the draft and stopping up the leaks that were found in the brick walls of the furnace, and by cutting down by one-half the air that entered the furnace, we very shortly increased the percentage of carbonic acid to 17 per cent.

In this machine is there any way of localizing the defects of combustion and telling just where it occurs?

Mr. Kebby.—Of course, we can discover quite readily any defects in the setting, if any are there. If there is a crack in the boiler wall, and the air rushes in, the Econometer, applied in two different places, will show the difference in the carbonic acid. The moment more air is admitted it reduces the percentage of carbonic acid. If the per cent. of carbonic acid is low, we are getting too much air, and we must regulate the damper in the stack and the ash-pit doors, and cut down the draft as much as possible. When we get too high a percentage of carbonic acid, and the boiler makes

steam too rapidly, we must cut down the size of the grate. In some of the establishments in Europe the size of the grate has been reduced one-third. Of course, that means that they had previously been burning more fuel than was necessary.

The cotton in the filter must be changed once in about two months. The calcium chloride will probably need renewing more often. It depends upon how close to the boiler the machine is, and upon how dirty the coal is. The chloride should generally be renewed when it is melted down about one-half.

I placed the first Econometer about a month ago, and I have just sent another one out. It is rather hard to place anything here until people can see for themselves just what it is. I do not expect to have much trouble in placing a great many as soon as the people can examine it thoroughly for themselves. Thus far I have had no trouble in getting engineers to understand the benefits which can be obtained by the use of the instrument.

Mr. Grunsky.—I have read of another system of weighing, and that was by means of an inclined tube containing water. The measurement was obtained or shown by the displacement of the water. The details of the instrument I do not know anything about.

Mr. Kebby.—That is what we call a gas-absorbing econometer. It does not make a continuous analysis as the Econometer does. In the gas-absorbing econometer the gases are pumped into a receiver in the machine, and then those gases are absorbed by the liquid; and, as they are absorbed, the air in the chamber is displaced or rarefied, and the water in the tube is raised. The tube is graduated to show the percentage amount of carbonic acid.

Mr. Grunsky.—In the appliance I have in mind I believe the weight of the gas displaced the column of water. In order that the displacement might be perceptible, the tube containing the liquid was placed nearly horizontal in order to have it as large as possible.

Mr. Kebby.—As far as I know, this is the only instrument of the kind which continuously works automatically. This gas-absorbing machine works nearly as you say, but, of course, it is not automatic. You can readily understand that when the weight of gas displaces the water the gas has to be pumped out. There is no means of escape.

Mr. Grunsky.—There was a small weighing contrivance, and I think there was a continuous flow of gas through the machine.

Mr. Kebby.—The scale on this machine is very delicate. It works practically in an air-tight chamber, and the knife edges are all of agate.

Mr. Molera.—There is no contrivance to give a graphic record?

Mr. Kebby.—No; but I have been studying the problem of providing one. The great difficulty in that direction is the delicacy of the scale. A ray of light thrown on a point might be photographed. It might be worked on the same principle as a galvanometer for delicate scientific measurements. That would certainly do for work of that kind. But for ordinary, every-day use I am afraid it would be too expensive.

Mr. Molera.—I suppose everything needed is supplied with this machine?

Mr. Kebby.—The owner of the plant supplies the pipe, which is a very small item. The price of the Econometer is $150. The filters, of course, can be placed anywhere, as, for instance, near the boiler, and the scale is placed within a cast iron box. The Spring Valley Water Works has one of these instruments in use at Black Point. I suppose it will work where oil is used as fuel. I do not know that it matters whether oil or wood or coal is used. The gas-absorbing apparatus is used for marine purposes. It must be very steady. If the position of the box or any part of the weighing apparatus is changed the instrument is thrown out of balance, but in any ordinary boiler room it can be so placed that it will not be disturbed. Only a delicate instrument will do the work properly.

Mr. Grunsky.—Does the smoke itself interfere when the combustion is imperfect, and when the air is highly charged with carbon that has not been consumed? Does that materially affect the gas filter?

Mr. Kebby.—If the gases are very dirty and have a tendency to clog the filter, the rubber tube can be disconnected at the instrument, and then, by blowing back through the filter, the dirt from the gases readily passes out. That is the common usage. If the coal is dirty the pipes between the furnace and the instrument will have a tendency to clog if left for some length of time, but this can be avoided by disconnecting the rubber tube, as I have said, and blowing through the pipe.

Q.—How long has this instrument been in use?

A.—I think it was first brought out in Europe in 1893. It was first brought to this country in 1894.

THE ELECTRIC MOTOR IN SHOP AND MINE.

By Clarence M. Barber, Member of The Civil Engineers' Club of Cleveland.

[Read before the Club, October 25, 1898.*]

The highest point that science has reached in this century and especially in our day is marked by its exploitations in electrical engineering. In this field, but standing a little back from the foreground, we find the electric motor.

It is not my purpose to enter into a theoretical discussion of this machine, but rather to note a few points bearing upon its present status in the shop and mine, and possibly to bring out a few points that may be of interest to the engineer who is not an electrician but who is interested in electrical power transmission.

The advent of the electrical motor has been so sudden and its field so wide that in many places its application has been accidental rather than otherwise, and we have just reached a period in the progress of electrical engineering where the electric motor is beginning to overtake its history, or in other words, it is just now doing what its over-sanguine friends claimed it was doing several years ago.

Street car propulsion early demanded attention and contributed perhaps more than any other one thing to the development of a hardy, healthy class of motors. The present status of the street car motor leaves but little more to be desired. Small motors, and in a few cases large motors, have been in use for other purposes in the last few years to a limited extent, especially in the shop and mine, but now the electrical engineer is going deeper into the problem than ever before.

The development of the shop motor at the present moment is remarkable. We seem to be entering upon a new era.

It is American-like to push forward anything that is worthy the attention of bright educated minds and capital. American activity and brains have taken hold of not only the conversion of mechanical energy into electrical energy, but the re-conversion of the latter into mechanical effect. The result of this is that the application of the electric motor to the driving of almost every class of machinery is being pushed.

The claims which the electric motor has upon the shop and mine are based upon the ease with which it can be applied to

*Manuscript received November 12, 1898.—Secretary, Ass'n of Eng. Socs.

almost all the purposes for which power is required, economy of installation, saving of power and many other incidental advantages.

The absence of overhead shafting and belting in many cases is a great consideration, especially as these often prevent or interfere with the use of overhead cranes. In fact, large traveling cranes are now indispensable in all shops where heavy work is handled, and these preclude the use of belting and overhead shafting within the areas served by them. Even in case of small jib cranes the belting and overhead shafting are almost invariably in the way.

This consideration alone in many shops is of sufficient importance to outweigh any prejudice that may exist against electric power transmission, especially since the motor has arrived at the stage where it is able to fulfill the requirements. The removal of belts and shafting greatly favor cleanliness and better light, and the roof supports, not being required to carry shafting, allow higher ceilings and better designed buildings. The writer, however, would not convey the idea that all shafting and belts are to be entirely dispensed with, although under some circumstances no shafting or belting need be used.

It is a valuable consideration to be able to place a machine at any angle with the meridian or at any distance from the source of power.

The removing of a machine from one part of the shop to another if it has its own motor attached to it is not a serious matter. Large machines, such as punches and shears, are now sometimes built with motors attached and arranged so that the whole may be turned on ball bearings about a vertical axis through any desired angle.

The dispensing with belting and overhead shafting is accomplished by placing a motor on each machine. This makes each machine complete in itself. It is started or stopped, made to run fast, slow, or reversed without regard to any other piece of machinery. This is an ideal condition both as regards each machine in its individual relation to the whole shop and as to its consumption of power.

The first cost of an electric shop power installation is in most cases more than an installation with shafting and belting. The cost of maintenance is less. The comparative cost of transmitting power by the two systems is of course the most important question involved. Theoretically the power lost in transmission by means of shafting is small. Some tests by the writer show that it may be below 10 per cent. in a shop of considerable size under

favorable conditions, but it seems difficult to realize as good results under such conditions as are usually found. According to Professor J. J. Flather, the loss of power in shops due to transmission by belting and shafting averages about 40 per cent. of the total power developed. He mentions among others the case of the Baldwin Locomotive Works, where 80 per cent. of the power is lost in transmission through shafting and belting. He also notes the case of J. A. Fay & Co., woodworking machinery, where only 15 per cent. of the power developed is required to drive the shafting. In the first case the loss is doubtless exceedingly high; no other case that he mentions show over 50 per cent., and the next to the lowest is 23 per cent.

Henthorn gives the result of 55 tests in New England shops at 26 per cent. loss; Fessenden gives the mean of 108 tests at 69 per cent.

These results show a great variation, which is probably due to variation in the distance over which the power is transmitted, to the character of the machinery driven and in a great measure to the alignment of the shafting as well as to the lubrication. Added to these is the personal equation of the party making the tests.

It seems to the writer that we may assume as a fair average the loss of power by transmission through shafting and belts for the purpose of this paper to be 30 per cent.

In regard to the losses through transmission by electricity. These losses are: the loss in the generator, the loss in transmission through the line and the loss in the motor. This includes two transformations.

In the first of these, the loss in the generator, if it is a well-designed machine and running under a full load or a load that is not too far from that for which it was built, need not be over 6 per cent.

In case of the loss by transmission through the line wire this is determined by the amount of copper in the line and the potential of the current. As the latter in shops is usually a constant quantity and generally about 225 volts, the loss will vary with the amount of copper. It is not difficult to confine the average loss to within 6 per cent. The third loss, that in the motors, will be somewhat more than that of the generator, due to greater variations of load, and on account of greater number of machines. The losses that are inherent in the motors themselves will be somewhat greater. The writer thinks the third loss should not average more

than 10 per cent. This would make the total average plant loss equal 22 per cent.

There are reliable companies that install electric power transmissions who advertise that their average plant losses do not exceed 15 per cent.

While long lines of shafting are almost sure to become out of line, and deteriorate from other causes, electric wiring when well put up, and in fact dynamos and motors when properly installed and cared for, and not overloaded so as to raise their temperatures so high as to endanger the insulation, will remain practically permanent.

There is an incidental point in favor of electric transmission that is very important. It is noticed in all shops that there are always a number of machines that are not running; if electric transmission is used the time that these machines are idle is a credit to the power plant, and as this quantity is within certain limits a constant, it follows that the engine and dynamo may safely be reduced in size on this account.

As an example: The American Lithograph Company, of New York, has a total capacity of engines of 660 horse power, a total capacity of generators of 590 electrical horse power. The rated capacity of all their motors is 847 horse power, and beside this they have 3000 incandescent lamps and 140 arc lamps. Their total generating capacity is only about 50 per cent. of what would be required if every motor and every lamp were on at the same time and every motor had its rated load.

What is still more remarkable, it is stated that their average load is only 17.6 per cent. of the rated capacity of all arc, incandescent lamps and motors, and the maximum load is 32.7 per cent.

The above is of great importance to power companies, as it enables those who supply current for a large number of small motors that are used for various purposes, as is the case with many power plants, to sell from two to three times the amount of power that they are able to generate.

The fact that the energy absorbed by the motor is proportional to its load also contributes toward reducing the load on the generators. Taking all these points into consideration it is not difficult to see how the above-rated results are obtained.

Another incidental point in favor of electric transmission is the fact that it is very flexible. The motors are capable of a variation of speed over a wide range. Motors with shunt wound fields are built for a constant speed that is predetermined, or they

may be run at any one of say six constant speeds forward, or two or more back-up speeds, the strengthening or weakening of the fields being easily controlled by a rheostat. This permits simplifying a machine where more than one speed or reversal of motion is required, less intermediate gearing being necessary.

The series wound motor resembles in the matter of speeds an engine without a governor. It must be controlled by the hand of the operator, or run under a constant load. Motors of this class respond quickly to the movement of the rheostat and are used wherever the hand of the operator controls every motion, such as for traction hoisting, cranes, etc.

The recent advancement in the development of the multiphase current motor shows that a great deal has been accomplished along that line, and but little seems to remain to be done before this beautiful form of motor will compete with continuous current machines.

For some time after the introduction of electric power transmission it was difficult to obtain slow speed motors. In fact it is only recently that motors have been on the market that can be said to run at slow speeds. This was not due entirely to the inability of manufacturers to produce such motors, but to the fact that they were generally occupied with other problems. Now, however, the want is supplied and motors of even small power can be obtained to run at 150 or even 100 revolutions per minute. Of course slow speed motors are like slow speed engines, they are larger and more expensive than those made to run at the higher speeds.

It is always best for the engineer who is designing machinery which is to be electrically driven to favor the electrician by using as high a speed as is consistent with other considerations, at least not to gear down toward the motor.

The electric motor early found its way into coal mines, and now does the hauling of the coal from the interior to the tipple, and the hoisting or pumping, as well as the drilling or undercutting. Freight on coal is not an item of expense near the slack pile at the mouth of the mine, so long distance transmission is seldom required at coal mines.

In gold and silver mining the most important work of all cannot as yet be performed by the electric motor. The diamond drill works well when driven by electricity. It is largely used for prospecting and occasionally for sinking of shafts, but it cannot take the place of the percussion drill. Many attempts have been

made to displace the pneumatic percussion drill by an electric drill, but, so far as the writer is informed, without success.

That an electric percussion drill can be made there is no doubt, but none have yet been made that fulfill the requirements. The fact is, the pneumatic percussion drill has been brought to a high degree of perfection, and it is very doubtful if it will ever yield its place to another. The exhaust air from the pneumatic drill is an advantage in mines, but not a sufficient cause for retaining the air drill if electricity could do the work as well.

However, the electric motor is not compelled to stand entirely aside even on the question of drilling granite rock. Wherever a question of long distance transmission is included in the problem, the electric motor comes in for its share, and is invited to stand behind the pneumatic drill and drive the air compressor. This, of course, introduces a second transformation of energy, but it cannot be avoided at present, except where the compressor can be driven directly by steam or water.

The great problem of producing a governor that will regulate a water power under varying loads has been brought so near to a solution that the water powers of the mountain mining regions of our country are now available for producing power that is to be electrically transmitted from the rivers and smaller streams up the steep slopes of the mountains to the points where gold, silver, lead and copper are mined.

DISCUSSION.

Prof. C. H. Benjamin.—I have been very much interested in this subject, and have made experiments along some of these lines. Mr. Barber has quoted some figures with regard to friction of shafting in shops. Several years ago I made a number of experiments in this city to determine the friction of the shafting as compared with the work being done. I visited a dozen or more establishments, some using large and some small machines. The largest amount of power used in driving shafting was about 80 per cent., and the smallest amount was 14 per cent., the average for the whole number of estimates, including both light and heavy machinery, was about 55 per cent. The results of these experiments have been quoted by electrical manufacturing firms to argue in favor of electric motors. Now, while I believe in electric motors in shops, I do not believe that this is the principal reason for their introduction. In nearly every establishment the expense for power is small; in some it is only 1 per cent., including the wages of the men, and in the majority it will fall below 5 per cent., so that a saving of even 50 per cent. in the coal bill is not so large an item.

The principal reason for the introduction of electric motors into shops is the fact that it will, in many cases, increase the output per man per machine. It will make it cheaper to manufacture, to build machines, or whatever the production may be, of that establishment; the mere question of saving power is a minor one.

The principal advantage is in the matter of flexibility, the ability to extend the plant at any time, to move any machine in any direction, and the entire freedom from the necessity of alignment. One advantage is the use of the crane to handle heavy work. In one establishment the principal reason for the introduction of the electric motor was that traveling cranes might be used. The saving by using cranes instead of men has been enormous. I have brought with me copies of two papers, one on "Friction H. P. in Factories," and the other "Electricity *versus* Shafting in the Machine Shop," and I would be glad to have the members help themselves to these papers.

Mr. C. O. Palmer.—If there is one place more than another where electric motors are specially useful it is in coal mines. There we want light, and electricity will furnish all necessary. We want power for hauling, and it answers this purpose fully as well underground as on the surface. In thin (4 ft. thick) veins where we should otherwise have to take the top down so that the mules could pass through we can run an electric motor without doing so. This is a large saving of expense.

In the matter of fans, if the fan is located near the boiler house it is an easy matter to run it by steam power, but sometimes we wish to put in a fan to ventilate a long distance from the boiler house, perhaps a mile. We can simply run an electric wire and put the fan in, and in that case it requires only one man to look at the motor occasionally. Again, in the matter of pumping, by using electricity the pumps may be situated a long distance from the shaft, and the water may be pumped by electric power by simply attaching the motor to the pump; this saves a great deal of hard work. One very large item of expense in coal mining is in the amount paid the miners for digging the coal. Here coal cutters run by electric power have been introduced, and the saving is about one-half that which is paid to the miner, the remainder going to pay for operating the plant, and the interest on the same. This is probably where the greatest economy is shown, and so much so that in some plants where electricity is employed this is its only use.

Mr. I. H. Sherwood.—In making some tests recently I visited a shop where there was a great deal of heavy shafting.

There were eight long lines of shafting running from $2\frac{1}{2}''$ up to $4\frac{1}{2}''$ in the shop, and the shortest one would probably be 50 ft. or 60 ft., the longest being 120 ft., or more, and the belting was very heavy. One belt was 16" and about 35 ft. between centers, a very long span for such a heavy belt. The other belts, taken off from the main shaft to run the machines, were large belts 6" and 8" wide. Also there was a large pair of bevel gears, which were used to transmit quite a large share of the power, and the surprising part was that the friction was about 70 H. P., including engine friction, as shown by the indicator cards. After deducting a fair amount for the engine friction, there would be only about 35 or 36 H. P. for the shafting friction, or only about 10 per cent. of the total H. P. of the plant. It was a result which I did not expect, and I repeated all my experiments to prove my work.

I then investigated and found that the proprietors had made one of the best of investments. Their chief engineer was a thorough engineer. He had taken care of the shafting, and also installed it, and his orders were for one of his assistants go around the shop every month and line up every bearing. It did not take long to do it, and it was a good investment. The result was that while we were called in principally to give them the best method of installing electric power we advised them to keep their power just as they had it, and made some minor changes in other matters.

Mr. J. L. Gobeille.—In a shop where a few of the large machines must be run night and day, and nothing else is run night and day, I think the machines should be run by motors, each machine separately; it saves the power, the wear and tear on the shafting and danger of fire. At Russell & Co.'s plant, in Massillon, everything is done with electric motors. Each blower in their foundry is run by a motor. Their foundry is quite a long way from the main building, and there is no steam engineering connected with it. That is one of the shops where they have big things to turn out. I know of one woodworking machine that is running 4500 or 4600 revolutions per minute. In cases of this kind I believe it would pay, if a man had the nerve and money, to run these machines separately. I never saw it in print, and never heard it discussed, but I know that you cannot run a very fast machine and a slow one from the same shaft and have them both run satisfactorily. We can countershaft off when we have trouble until it runs right. Sometimes it takes quite a while to adjust everything properly. If we had motors I suppose we should not have that trouble. In mines I do not see how anything else can be

used. When we get the heating problem down, as we will some day, nothing will be used but electricity. When we can heat and light and run our tools from one plant economically then the millennium will be here.

Mr. J. A. Bidwell.—Some remarks have been made in regard to pumping water by electricity. I would ask whether any engineer here has had experience in that line, and how electricity is applied to a reciprocating motion?

Mr. Frank Houghton.—A few years ago I was manager of a plant in Dayton. It covers about four acres, and had four or five engines in different portions of the shops, and possibly averaged 1000 H. P. After going over the shops and figuring on installing motors to take the place of the engines I found that I could safely make a guarantee to furnish 500 H. P. in generators, or two 250's, to take the place of 1000 H. P. in engines, and if it was found, after the plant was started, that it required more power we would furnish any additional power free of charge, we were so sure that the 500 H. P. would do the work. The hard times came on at that time, and the company did not put in the plant, but it has since done so, and is running practically under that guarantee. Mr Barber spoke of the twist drill; I installed a plant at Amherst Stone Quarry a few years ago, and put in an electric drill. We found it worked well under the alternating current, except when they had to drill any great length of time, and then the drill would shift to one side, and the current was not strong enough to pull it out, and they had to discard the drill on that account; but for any short distance it was very much more satisfactory than the steam drill. There is one very remarkable thing in the efficiency of motors. With 100 H. P. in a motor and 100 in an engine, the efficiency of the motor would be, say 90 per cent. and that of the engine, say 70 per cent. Now, when there is a half load put on the motor, the efficiency is practically the same, possibly within 5 per cent. to 10 per cent.; when it is down to one-fourth load the efficiency is about 40 per cent. In the engine the efficiency at one-fourth load is at zero,—it is lost,—the whole power is consumed in running the engine itself. That is the result of the test made by the company I was with.

Another item that should be spoken of in favor of the motor in large shops where a large amount of shafting and belting is used is the cost of repairs to belts. It is generally said we can make so much of a saving in the coal bill, but the bill of keeping up the belts is very large, and that all goes to the credit of the motor.

Mr. John M. George.—I have been for many years one of

the most enthusiastic advocates of the electric motor, but we ought to be careful in accepting some of the statements made. The statement was made that the difference between 80 and 15 per cent. ought to go to the credit of the motor. I beg to differ. We would never dream of putting in such a plant as I have seen involving 80 per cent. loss, and such a plant as I have seen with 15 per cent. loss. I have seen many establishments where the loss has come up to 80 per cent., but they were not properly installed.

When I was with the Bullock Company we frequently made inspections, in some of which we found 80 per cent. losses. A great many of these were in machine shops. A machine shop is a peculiar installation; the power is required to be very heavy at times, but the bulk of the time very light. The average efficiency of shafting would not be more than 30 per cent. or 40 per cent. At Carnegie's they had about 4500 H. P. motors, and they were driven by 750 H. P. generators. That seems like a startling statement. If they had been steam engines it would have required about 4500 H. P., but the explanation is simply that they were widely scattered. With regard to saving, it is not merely in the coal bill, but in efficiency of service, keeping the shop clear of impediments and admitting more light. The more pleasant you make the shop the better work you will get out, and that is one of the great arguments in favor of the electric motor, because it enables us to remove the dirt from the shop. Another thing is the flexibility; we can put motors where we can put nothing else. A shunt motor, if working steadily, will show great efficiency, but when we vary the speed, as in ironworking, then the efficiency disappears. We have not yet found an efficient means of regulating the speed as required by machine tools. The series motor is well as long as it is governed by hand, but when we slow down a motor by resistance a serious loss takes place. The current is divided into three parts, the first part of it is choked back by the resistance, and another part is forced through the resistance, and there is where the loss takes place. We lose energy in the form of heat. I would like to know whether there is any means of regulating an electric motor in any other way than through the loss involved in resistance. I also would have liked to hear whether any steps have been taken toward designing a motor which will run steadily under the different speed conditions, and can be regulated to the degree of speed required, to cut material at different velocities of lathe.

Mr. Houghton.—The shunt motor is regulated through the rheostat, and the loss is just the same; it is lost in the rheostat itself,

and I know of no other way of avoiding that loss. The speed regulators are carried only as a handle of the rheostat. As the rheostat is turned from point to point we get the speed regulation between these points, and that is all. If we have 1200 revolutions and the next point gives 1000 and the next 800 there is no way of getting 900 or 1100.

Professor Benjamin.—I am not an electrical engineer, and I know very little about motors, or the eccentricities of their construction, but I know there are several firms who guarantee to be able to furnish a motor which will give the slow speed necessary for ironworking without any special loss. The Bullock Mfg. Co. has them, and I have seen the results of a test, which, if reliable, are very remarkable. The results were published in "Cassier's Magazine" about a year or two ago, and if they are correct the problem is solved.

Mr. Houghton.—I think the way most of the companies build motors for slow speed is to take, for instance, a 3 H. P. frame and put the extra winding on it, and in that way get a very slow speed. If you increase the size of the motor, you reduce the speed; motors can be placed on almost any machine, but where very slow speed is required they have to use a very large motor.

It might be interesting to know the price of operating motors. Last year the Illuminating Company had something like 1500 H. P. connected up, and the amount of money received showed the average cost per H. P. per month was $2.10 for operating a motor from the lines of the Cleveland Electric Illuminating Company.

Professor Benjamin.—For those who wish further information in regard to the Bullock Mfg. Co.'s machinery I would say that in one of the papers on the desk there is a cut of the Niles Tool Works, equipped with a Card motor.

STATE, CITY AND TOWN BOUNDARIES.

By Henry B. Wood, Member of the Boston Society of Civil Engineers.

[Read before the Society, April 25, 1898.*]

A boundary, in its original and strictest sense, is a visible object or mark indicating a limit, as of a territory; in practice, it may be a real or an imaginary limit, and hence may be indicated by visible marks or not, as the case may be. The state limit or boundary of land bordering on the sea is an imaginary line following the coast or high water line and one marine league therefrom, while individual ownership of such land extends only to extreme low water in this State, a stipulation made law by a special ordinance of 1647.

Natural streams or bodies of water are often used for boundaries between towns, the boundary line sometimes being the middle of the stream, the middle of the channel of the stream, and sometimes the high water line on the bank. In either case it is not always an easy matter to decide just where the line is located, as the stream is subject to change.

The old Province Laws recognized the importance of establishing the bounds of a colony, and made it obligatory on the officials to periodically view the markings, out of which grew the law relative to the powers and duties of towns, St. 1785, Chap. 75, and later as given in the Public Statutes, Chap. 27, which is as follows:

"Section 3. There shall be a perambulation of town lines, and they shall be run and the marks renewed once in every five years by two or more of the selectmen of each town, or by such substitutes as they in writing appoint for that purpose. After every such renewal the proceedings shall be recorded in the records of the respective towns.

"Section 4. Before a perambulation the selectmen of the most ancient of the contiguous towns shall give ten days' notice, in writing, to the selectmen of the adjoining town of the time and place of meeting for such perambulation; and selectmen who neglect to give such notice, or to attend either personally or by their substitutes, shall severally forfeit twenty dollars, to be recovered on complaint to the use of the county, or by action of tort to the use of the town whose selectmen perform their duty.

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"Section 5. The selectmen of the contiguous towns shall erect, at the joint and equal expense of such towns, permanent monuments to designate their respective boundary lines at every angle thereof (except where such lines are bounded by the ocean or by some permanent stream of water), and wherever a highway crosses such lines. The monuments shall be of stone, well set in the ground, and at said angles, at least four feet high from its surface, and the initial letters of the respective names of such contiguous towns shall be plainly and legibly cut thereon; but it shall not be necessary to erect a new monument at said angles in a place where a permanent stone monument two feet in height above the surface of the ground already exists.

"Section 6. The selectmen of towns bordering on another state, where the lines between the states are settled and established, shall once in every five years give notice to the selectmen or other proper municipal officers of such towns in the other state as adjoin their towns of their intention to perambulate the lines between their adjoining towns. If such notice and proposal are accepted by the officers to whom they are made, a perambulation shall be made in the same manner as between towns in this Commonwealth. No boundary erected by authority of this Commonwealth and an adjoining state shall be removed by such selectmen or other municipal officers.

"Section 7. A selectman who refuses or neglects to perform any duty required of him by the two preceding sections shall forfeit twenty dollars."

The marks usually left under the regulations of the Province Laws were a stake and stones, or simply a pile of stones, or a tree or stump. Indefiniteness is a common fault. A portion of our own State lines—the Rhode Island line—is described by the commissioners appointed by that State to run out and mark the line in the following language, which illustrates the lack of permanency of the bounds:

CUMBERLAND LINE.

"We, the subscribers, appointed Commissioners by the General Assembly of the colony aforesaid to mark out the bounds of said colony eastward toward the Province of Massachusetts Bay, agreeable to His Majesty's royal determination in council, the 28th day of May, 1746, did, in pursuance thereof, on the second day of December last past, meet at Pawtucket Falls, in expectation of meeting with Commissioners that might be appointed by the Province of Massachusetts Bay, for the purpose aforesaid; and after having there tarried till the afterpart of said day, and no Commis-

sioners in behalf of the said Province appearing, we proceeded to run a due north line from Pawtucket Falls to the south boundary of the aforesaid Province of Massachusetts Bay, in manner following, viz. from a certain point on the southern side of Pawtucket Falls, where we erected a monument of stones, with a stake thereon, we run a meridian line, which directly passed through said falls, to a walnut tree on the northerly side of said falls; then to a pitch pine tree; then to a small white oak; then to a grey oak; then to a small bush; then to another small bush with stones about it; then to a heap of stones with a stake thereon; then to a black oak tree; then to another black oak; then to a small pitch pine; then to a black oak; then to a large white oak near the river called Abbot's Run; then to a poplar tree; then to a heap of stones with a stake thereon; then to a large rock with stones thereon; then to a small black oak tree; then to a walnut tree; then to a black oak; then to divers other marked trees in the said course, to the extremity of said line; and when we came near the termination of the said line, made a monument of stones, there being no noted south boundary of the said Province near the said line, and, therefore, for the discovery of the south boundary of the said Province, upon the best information we could obtain, proceeded to Wrentham Plain, at or near to a place where was formerly erected a stake called Woodward's and Saffery's stake, as one remarkable south boundary of the said Province, etc." * * *

One of our town lines—the Amherst-Granby line—is described as follows:

Corner No. 1.—Oak tree.
" No. 2.—Two walnut trees.
" No. 3.—Dead pine tree, stones around it.
" No. 4.—Black oak stump, 10 feet high, badly decayed, with stones around it.

The South Hadley line is described in part as follows:

Corner No. 6.—Two small hickory trees with stones.
" No. 11.—Treble hemlock on peak.
" No. 19.—Maple near birch stump.
" No. 20.—Black oak near dead pine.
" No. 23.—Black oak over the summit.
" No. 30.—Small maple in valley.
" No. 34.—Dead hemlock.
" No. 42.—Black oak west of dingle.

This line, originally defined by 51 similar "monuments," was straightened and re-marked in 1895 with 10 bounds of granite or iron.

Another description reads: "From a stake in the ice the line runs northerly 970 rods to a pine tree with a bird's nest and one egg in it" * * * * and another ends: "In the center of fourteen chestnut oaks on the side of Pine Mountain."

To provide against controversies likely to arise from an attempt to survey and mark boundaries of such fickle and indeterminate character, a law, as above quoted, was made compelling the selectmen of every town to faithfully attend to those duties.

It would seem to follow that each town or state line would be well marked and correctly so, and it would only remain to go to the town or state records to get a good description, and to provide for these locations by some of the modern methods of surveying that would admit of an accurate plot. But the law is not enforced and regular perambulations are not made in all cases.

STATE BOUNDARIES.

A recent paper read before the Boston Society of Civil Engineers by Mr. Frederick H. Newell, Chief Hydrographer of the U. S. Geological Survey, upon the hydrographic development of the United States, referred interestingly to the boundaries thereof, showing that the limits of the United States were first definitely laid down in the provisional treaty made with Great Britain in 1782, defining the boundary between the United States and the British possessions; 2d, the treaty of 1795, defining the boundary between the United States and the Spanish possessions, known as the Floridas. As it is well known, the northern boundary has been a bone of contention to the present time. It was extended along the forty-ninth parallel to the "Stony" (Rocky) Mountains in 1818, and a few years later to the Pacific, claims being made by contending parties as to territorial rights. The King of the Netherlands was selected in 1829 by both Governments as the arbiter, who made an award in 1831. Here for the first time the principle was established that the Government of the United States had not the power to change the boundaries of a state without the consent of the state, Maine being the first to enter à solemn protest, which was confirmed by the United States Senate; hence arbitration failed. Agreement was reached later with the consent of Maine.

Additions to the territory of the United States have been made from time to time, notably the Louisiana purchase from France in 1803, Florida from Spain in 1819, Texas being admitted as a state in 1845, the Mexican cession of 1848, including the Gadsden purchase of 1853, and Alaska in 1867, the consideration paid being

$7,200,000 in gold. The exact boundary of Alaska is a matter of great interest at the present time on account of the Klondike fever, one of the contested points being whether measurement shall be made back from the general shore line of islands or from the general shore line of the main land.

Of the thirteen original colonies, many possessed unoccupied territory west of the Appalachian Mountains, Massachusetts, among others, laying claim to areas in what was afterward known as the Territory Northwest of the River Ohio, a region now comprising Ohio, Indiana, Illinois, Michigan and Wisconsin. These claims being more or less conflicting and the boundary lines in most cases being ill defined, it was generally contested, especially by states having no such claims, that the resources of the General Government should not be taxed for the protection and development of this region to the benefit of a few. Following an act of Congress of 1779, the different states made cessions of this character, each transferring her territory to the General Government.

Massachusetts ceded an area west of a meridian line from the forty-ninth degree north latitude through the westerly bend of Lake Ontario, thence by said meridian line to the most southerly side line of the territory contained in the Massachusetts Charter, provided this line did not comprehend 20 miles west of the strait of Niagara.

The Massachusetts claim extended from the north line of the Connecticut claim northerly, and from the eastern boundary of New York to the Mississippi. It was ceded April 19, 1795.

The territory of Massachusetts was included in the first charter of Virginia, granted in 1606, and in the charter of New England, granted in 1620.

In 1628 the Council of Plymouth made a grant to the Governor and Company of Massachusetts Bay in New England, confirmed by the King and charter granted in 1629.

Extract:

"Nowe Knowe Yee, that Wee * * * have given and granted * * * all that Parte of Newe England in America which lyes and extends betweene a great River there commonlie called Monomack River, alias Merrimack River, and a certen other River there, called Charles River, being in the Bottome of a certen Bay there, comonlie called Massachusetts, alias Mattachusetts, alias Massatusetts Bay, and also all and singuler those Landes and Hereditament whatsoever, lying within the Space of Three Englishe Myles on the South Parte of the said River called Charles River, or of any or every Parte thereof. And also all and

singuler the Landes and Hereditaments whatsoever, lying and being within the space of Three Englishe Miles to the southward of the southermost Parte of the said Baye, called Massachusetts, alias Mattachusetts, alias Massatusetts Bay—and also those Lands and Hereditaments whatsoever, which lye and be within the Space of Three Englishe Myles to the Northward of the saide River, called Monomack, alias Merrymack, or to the Norward of any and every Parte thereof, and all Landes and Hereditaments whatsoever, lyeing within the Lymmits aforesaid, North and South, in Latitude and Bredth, and in Length and Longitude, of and within all the Bredth aforesaid, throughout the Mayne Landes there from the Atlantick and Westerne Sea and Ocean on the East Parte, to the South Sea on the West Parte."

This charter of New England was surrendered to the King in 1635 and a new charter was granted to Massachusetts Bay, which included Plymouth Colony and the Provinces of Maine and Nova Scotia. When Maine was admitted as an independent state, 1620, steps were taken to agree on its boundary, first settling the New Hampshire line, which took nine years. New Hampshire originally claimed jurisdiction as far west as the territory of Massachusetts and Connecticut extended, thus including the present State of Vermont, while New York at that time claimed all the country west of the Connecticut. A decree of the King in 1764 established the Connecticut River as the boundary line between New Hampshire and New York, which line became the boundary between New Hampshire and Vermont, as it is to-day. The above facts are gathered from Mr. Henry Gannett's sketches as recorded in the Geological Survey bulletins.

BOUNDARIES OF THE COMMONWEALTH.

1.—Massachusetts-New Hampshire-Vermont Line.

The controversy between the Provinces of New Hampshire and Massachusetts Bay (the commissioners being unable to agree) led to an appeal by New Hampshire to the King, who ordered the matter settled by a Board of Commissioners appointed from the neighboring colonies. Their decision of 1740 was as follows:

"That the northern boundary of the Province of Massachusetts be a similar curve line pursuing the course of the Merrimac River, at three miles distant, on the north side thereof, beginning at the Atlantic Ocean and ending at a point due north of Pawtucket Falls, and a straight line drawn from thence, due west, till it meets with His Majesty's other Governments."

George Mitchell and Richard Hazen were appointed by Mr. Belcher, then Governor of both provinces, to survey and mark the line, with orders to allow for a westerly variation of the needle of ten degrees. Mitchell ran the first portion and Hazen ran from the point north of Pawtucket Falls westerly. This was the recognized boundary line from 1741 to 1825. It was thought that Hazen's line ran too far north; at least it was so asserted by George Sproule (1774), who based his calculations on actual surveys and astronomical observations. The Massachusetts Commissioners contested this claim, on the ground that they were to mark the original line only.

In 1827 the original line was marked by suitable monuments, by order of the Legislature, and Borden's survey of 1830-8 was connected with them, which throws light on the true course of the Hazen line as marked by the commissioners of 1827. From 1827 to 1885 the Hazen line, as far as occupancy is concerned, has been the recognized jurisdictional line, although in theory the New Hampshire authorities have claimed the territory of about 60,000 acres, or about thirty towns, between that line and a due west line. From 1885 to the present time a special commission for Massachusetts has been endeavoring to co-operate with similar commissioners of New Hampshire and Vermont, and have monumented a line along the line of occupancy from corner to corner as found marked, with some variations from a straight line. This line, as marked, has been only partially ratified, a final report being nearly ready for submission to the respective Legislatures.

2.—The Massachusetts-New York Boundary Line.

The State of New York included the French and English grants of 1603 and 1606. The Dutch, in 1613, established trading posts along the Hudson River, and claimed jurisdiction over territory west of the Connecticut and east of the Delaware. In 1664 this territory was given by King George II of England to his brother, the Duke of York.

As stated in our Commissioner's Report for 1897, "The royal commission which had been sent out to visit various colonies in New England, and which had been given, among other duties, that of determining the boundaries between different colonies in disputed cases, declared the western boundary of Massachusetts to be a straight line twenty miles easterly from Hudson River and parallel with its general direction in this latitude. The location of the southerly end of the line appears to have been generally agreed to, but the direction of the line was the cause of much dispute.

"In 1767 the King referred the determination of the boundary to commissioners to be appointed by each province. In May, 1773, commissioners from both states met at Hartford, and after some discussion made a mutual indenture, stating that the line should be run from what was known as 'Connecticut Old Corner' parallel to the general course of Hudson River, which was agreed to be north 21° 10′ 30″ east. This was precisely the boundary which had been recommended by the King's commissioners ninety-nine years before. The above bearing had been determined by a survey of the river during the previous winter. The commissioners then started to run the line on the ground. After running by range poles about twenty miles the Massachusetts commissioners, finding that the line was bearing more to the east than it would if run by compass, owing to an increase in the variation of the magnetic needle as the survey proceeded northward, insisted that it should be run by compass from the beginning. This the New York commissioners would not agree to, and the dispute resulted in a suspension of the work.

"Nothing further was done until after the Revolution, when the dispute was brought to the attention of Congress; and a commission, consisting of Thomas Hutchins, Rev. John Ewing and David Rittenhouse, was appointed by Congress to run out and mark the boundary line between the State of Massachusetts on the east and the State of New York on the west. Thomas Hutchins was educated as a military engineer, and served as Geographer-General in the army under General Greene during the Revolution. Rev. John Ewing was vice-president of the American Philosophical Society, and a man of many scientific attainments. David Rittenhouse was a distinguished clock-maker and instrument-maker, and was employed, in addition to this work, in fixing the boundaries of Pennsylvania, New Jersey, New York and other states. The principal instrumental work of this survey was done by Mr. Rittenhouse. These commissioners began at the southerly end of the line, at what was then the southwest corner of Massachusetts, known as 'Connecticut Old Corner,' and ran a straight line north 15° 12′ 9″ east of the true meridian, in substantial accordance with the agreement made at Hartford in 1773, which stipulated that the line should proceed '21° 10′ 30″' eastward from the then magnetical meridian, the proper allowance for variation in magnetic declination being carefully determined and computed for the south and north ends of the line, and for the period of fourteen years elapsed since the time of the decree. The line ended at a red or black oak tree in the northerly boundary line of Massa-

chusetts, not found at the present time. The points were marked on the summits of hills crossed by stakes, around which were placed piles of stones and at occasional points by cuts in the ledges. Between these stakes on the summits lines were run by a good compass, and other stakes with piles of stones were placed at each mile point, counting from the southerly end. No other marks were placed on this line by the commissioners, but at various times since then stone bounds and other marks to identify town and property lines have been placed by local authorities and by surveyors on what they considered to be the boundary line." (See report of Topographical Survey.)

In 1853 a small area of about 1000 acres in the southwestern corner of the State, and west of the mountain summits, was ceded to New York by Chapter 340 of the acts of that year. This section was known as "Boston Corner," and was given to New York to insure proper police protection against prize fights and other acts of lawlessness not easily regulated by the authorities on the east side of the mountains on account of inaccessibility.

Thus the line has remained until the year 1887, when, under the authority of the New York State Engineer and Surveyor, the Wilson survey was made. This survey was established by assuming a few points at the southern end of the line, about two and a half to five miles apart, the monument at "Boston Corner," a mark that appeared to be the "Crow's Foot" cut at Alander, and points on Cedar and Prospect Mountains, as the best authentic evidence of the direction of the line, and then translating this short line northerly in the direction thus determined. The result was that the stone piles which were found were mostly on the easterly side of this base line, and varied in offset from a few feet in the southern portion to 108 feet at the northern end of the line. An opinion was given that only ten of the points found were really the original markings, and that all the stone piles between the eighth mile-post and the forty-first mile-post were very uncertain, and were mostly local. This survey was done wholly at the expense of the State of New York. The line was not chained.

The Massachusetts authorities were invited to join in remarking the line at that time, but, having no act of legislature to legalize such a proceeding, they were compelled to decline.

In 1897, however, the Massachusetts Legislature authorized the Topographical Survey Commission to co-operate with the officers or agents of the State of New York to locate, define and mark the true line, and a survey was undertaken. Taking advantage of the data and information previously gathered together and

carefully reported, it was thought best to lay out as the base line of the present survey a line which would more nearly correspond to the average location of the stone piles which had been found. This would naturally lead to the discovery of other stone piles not previously found, and the cutting over such a line could be done at less expense than in the thick young growth that now covers the location of the Wilson line. Furthermore, as Mr. Wilson had reported that Alander Mountain and Mount Misery, 38¼ miles apart, were intervisible, and as Berlin Mountain was recorded 200 feet higher in elevation than Mount Misery, it was thought probable that two points on the original line could be selected, one at Alander Mountain and the other on Berlin Mountain, which would be intervisible and enable us to establish a longer straight line base from which intermediate points on summits could be lined in exactly with a straight line instrument. The woods on the second knob of Mount Misery prevented our using Berlin, and Mount Misery was finally selected.

The instrument used was a Straight Line Transit (No. 90), made by Buff & Berger. The aperture is two inches, magnifying power forty diameters. The lenses were made by Clark, of Cambridge. It has three leveling screws, and can be accurately centered by a motion of the base. The height of one of the Y's is adjustable. The cross-hairs are of the X pattern, and are quite fine. It is provided with a delicate striding level. The axis is of hardened bell metal. The top of the tripod is very broad, and gives great steadiness. This instrument was originally designed for alignment of the tunnel under Dorchester Bay, in the construction of the Boston Main Drainage system. Heliotropes were used for signals.

Alignment of Base Line.

Alander was selected as the instrument station, as the light was favorable in sighting northerly.

With Buff and Berger special straight line transit No. 90 located at Alander, and set upon the flash at Mount Misery for a foresight, the flash at Mount Harvey was set on line eight times, approaching from opposite sides alternately, and the telescope being reversed in the Y's each time and adjusted with a striding level. The four points from the east were within a space of 1¾ inches, and the four points from the west were set within a space of 2 inches, while the distance between the two extreme points of both sides was only 6¼ inches, causing the means to fall within the space of 9-16 of an inch. This long sight from Alander to Misery was 38¼ miles.

As samples of transiting and alignment other than the one at Mount Harvey, above mentioned, the following may be cited:

With transit No. 90 on Alander Mountain, using the staff on Mount Prospect for a backsight, a group of east and west points was obtained by transiting and setting a target 2 feet square at "Boston Corner." The groups of sightings were $13\frac{1}{2}$ inches apart, and fell within a space of 2 11-16 inches and 1 11-16 inches respectively; and their average fell 13.75 inches east of the marble monument at "Boston Corner," set by Simeon Borden. The distances were: Prospect to Alander, $4\frac{1}{4}$ miles; "Boston Corner" to Alander, $2\frac{1}{2}$ miles.

With transit No. 90 at Mount Fray, on the eighth mile point, a foresight on Mount Harvey, or the nineteenth mile point, the 2-foot target was set eight times on the fifteenth mile point at Hillsdale, all within a space of $5\frac{5}{8}$ inches.

With the instrument at Mount Harvey (the nineteenth mile) and the heliotrope at Mount Misery (thirty-eighth and one-quarter mile), points were set at Cunningham's Hill, Perry's Peak, the thirty-second mile point, and on Round's Mountain, all with good results.

All of the points north of Mount Misery to the end of the line, covering about 13 miles, were set by transiting the line ahead. The triangulation controlling the line shows these points to be exactly on line, no azimuth as taken from the inverse computations of a common origin showing a greater variation than one-tenth of one second.

In all of the above work the best time of day for observing was found to be after four o'clock P.M., except, of course, on cloudy days.

As the base line of survey was proved to be a thoroughly straight line by subsequent primary triangulation which was brought to bear on it, its location with reference to the old stone piles and other marks left by the commissioners of 1787, as far as they could be identified, is the chief consideration for determining the boundary line to be adopted. About twenty-five marble monuments and over seventy stone piles were discovered, some on the line and some either east or west of it.

The offsets of prominent marks recovered are as follows:

Alander (crow's foot or arrow), 1.9 feet west of line.

Prospect (cut in ledge), 1.8 feet east of line.

Harvey (old stone pile), 0.7 feet west of line.

Marble monument (Richmond and Hancock corner), 0.0 feet.

Marble monument (Lebanon and Pittsfield road), 2.0 feet west of line.

Marble monument (Goodrich Hollow road), 3.0 feet east of line.

Marble monument (Shaker Village road), 1.65 feet west of line.

Mount Misery (stone pile transit post), 5.4 feet west of line.

Rhode's Pinnacle (stone pile transit post), 0.0.

Berlin Mountain (stone pile transit post), 8.0 feet east of line.

From a review of the offsets but one conclusion can be drawn, —viz. that this base line of survey is a good average of the 1787 points now recoverable on the ground, and therefore represents as well as may be the original boundary intended to be laid out. It will without doubt become the adopted boundary between the two states, and will be marked by suitable monuments.*

3.—*The Massachusetts-Connecticut Line.*

This line was settled by commissioners in 1713, but their contract being declared void on account of its not being approved by the King, no final agreement was reached till 1803, when the portion from the west bank of the Connecticut River to the northwest corner of Connecticut was both surveyed and marked. These marks are not all preserved. The portion from the Rhode Island corner to the east bank of the Connecticut was surveyed and marked in 1826. Most of these monuments can be found at the present time. Their condition will be a subject of investigation in 1898.

4.—*The Massachusetts-Rhode Island Boundary Line.*

Gannett says: "This line was for more than two hundred years a question of dispute, and was in some respects the most remarkable boundary case with which this country has had to do. Twice in the Supreme Court, and once with Daniel Webster and Rufus Choate as counsel for Massachusetts. As early as 1642 the line between the two colonies was marked in part by Nathaniel Woodward and Solomon Saffrey, who set up on the plains of Wrentham a stake as the commencement of the line between Massachusetts and Rhode Island. This stake was supposed by them to mark a point 3 miles south of the Charles River."

In 1880 and 1881 the northern boundary of Rhode Island was settled, after a continuous controversy since 1849, by marking a

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*Since the above was written, this line has been agreed upon by the authorities of the states, and it is being marked by large granite bounds 12 inches square and 9 feet in length at all highways and summits, and 5 foot bounds at each mile point, substituting cast iron posts set in cement concrete at inaccessible points.

jurisdictional line having the same termini as the line of 1848, but irregular, sometimes running north and sometimes south of it, the extreme variations being 529 feet north and 129 feet south. This line was well monumented, and an excellent plan filed in the State archives.

The easterly boundary line from "Burnt Swamp" corner to "Peaked Rock," at the Atlantic Ocean, was the dividing line between Plymouth Colony and Providence Plantations, and was almost constantly in dispute from its original establishment to 1861. Various attempts were made to settle it by commissioners appointed by the two states, and a settlement was finally agreed to by the commissioners in 1848. Their decision was ratified by the Legislature of Rhode Island, but not by the Legislature of Massachusetts. Suit was afterwards brought in the United States Supreme Court to settle the line, and in 1861 a decree was entered, with the assent of both states, establishing the line. A portion of the line fixed by this decree consists of a portion of the extreme high water lines on the westerly sides of South Watuppa and Sawdy Ponds, in Fall River, and the stream connecting them, and a portion of the extreme high water lines on the easterly banks of what are known as Seven Mile and Ten Mile Rivers, on the easterly side of the city of Pawtucket.

As many of the bounds marking the line were either lost or never set, and others were from 400 to 1000 feet distant from their true location, a readjustment of the line was desirable to be followed by marking the exact location on the ground in a plain and definite manner.

By Chapter 88 of the Resolves of 1897 the Topographical Survey Commissioners were authorized and directed, acting with any officer or agent appointed by the State of Rhode Island for a like purpose, to locate, define and mark a series of straight lines along the jurisdictional line between Massachusetts and Rhode Island, from the "Burnt Swamp" corner in Wrentham southerly to the sea, following as near as may be the line established by decree of the United States Supreme Court in 1861.

A complete reconnoissance of the line was first made and the survey followed, made by a joint party representing both states. The work was laid out on three distinct lines,—viz. triangulation, base line, or traverse work, and topography. Traverses were run, depending for accuracy upon the checks furnished by the triangulation. Existing monuments were located, and the topography developed where high water boundaries made it necessary. A full description of the survey may be found in the report of the Massachusetts Topographical Survey Commission for 1897.

The errors in chaining were only about 1 in 8000, and, as all important angles were covered and controlled by a system of triangulation direct from strong Coast Survey bases, there can be no uncertainty as to the accuracy of the results. It is intended to substitute for high water lines a series of straight lines, following as closely as may be the original boundary, and so laid out that the exchange of territory between the two states shall be equal. This will be followed by resetting all old monuments found to be off the line, and the establishment of new corners marked by granite monuments, 12 inches square and 9.5 feet long, set 4 feet out of ground. About 150 points in the whole 50 miles will thus be remarked, and the line, left in good condition, will doubtless be ratified by the Legislatures of both states.

5.—*Town Boundaries.*

The importance of an accurate determination of the boundary lines of towns was made very apparent to the Massachusetts Commissioners during the first year of the topographical survey of the State begun in 1884 in co-operation with the U. S. Geological Survey. They found many boundary lines of towns described in vague and misleading terms, distances erroneously stated, corners omitted, a common line between two towns recorded and described in conflicting terms in the records of the two towns, and in many cases no record. In fact, it was common knowledge that the records were wrong or incomplete, and that the lines were located, if located at all, by very crude and imperfect methods. The commissioners plainly stated that "a good topographical map, upon which the locations of town lines are accurately shown, would be a great auxiliary in identifying the positions of the various points and angles; but the determination of the lines should not be an incident in that survey, or depend upon the plottings of the map, but should, on the contrary, be effected with such precision as to be a basis for the survey itself, and form a framework, as it were, to which all other surveys within its limits could be referred."

Yet the topographical survey, as authorized, could not be extended to include so large and expensive a feature as the determination of town boundaries, although its necessity was fully set forth as follows:

"The system of determining town lines by triangulation was a part of Mr. Simeon Borden's masterly scheme of the State survey, devised fifty years ago, and was partially carried out and several points in the State boundary line were included in his triangulation,

but the determination of town boundaries was not practically carried out. Such a plan would give to the State Government, and to each municipality in it, a perfect record of the exact boundary of each city and town in the Commonwealth, and in so methodical and precise a manner that any city or town engineer or ordinary land surveyors could reproduce the exact position of any point in any line. The system of record should be uniform with that of the other geographical positions determined by the triangulation of the State survey, giving the latitude and longitude of each point, probably within one or two feet of its true position; whereas, as now described, many angles and even whole lines are probably out of position hundreds of yards, and in some places hundreds of rods."

That the information at hand was meagre is shown in their original estimate of the work involved. There were at that time 347 towns and cities in the Commonwealth, and the total number of points or angles in the boundary lines of all of them was reported as about 1700, while there have been located to date about 2500 corners, and the State is less than half done. In many towns that appeared to have from four to seven corners, we have found from twenty-five to thirty. Some towns have as many as seventy-five corners. The commissioners early confessed that they were unable to make a satisfactory estimate of the number of points in the boundary lines to be determined. The appeal to the Legislature for funds with which to undertake this work as a special survey led to a beginning of the work in 1885, and by successive appropriations from year to year it has been in progress until the present time. The first year's work brought to light the magnitude of the undertaking somewhat, and called forth a retraction of preliminary statements as to its probable cost and the time it would take to complete it, and, at the same time, a decided stand was made as to the feasibility of its accomplishment and the usefulness of its results.

The scheme of location has been to use, when possible, as a base line, some triangle side as determined by the U. S. Coast and Geodetic Survey or one established by the Massachusetts Corps of Engineers by extension of their work, and develop a secondary system of triangles to points at or near the corners themselves; in the latter case, to connect with the corner by a short traverse line or by measuring a small base with a tape establishing a small quadrilateral connection. (See Conn. River Triangulation.)

It was soon found, as the work progressed inland, that the larger triangulation, upon which the work is based, would have to

be extended, especially toward the interior and western section of the State, owing to a loss of the exact positions of certain of the triangulation stations of the earlier surveys, and also to discrepancies which arose when the work of the Borden triangulation of 1831 was compared with the more accurate work of the Coast Survey. The Borden system was not as strong in the western part of the State as it was farther east, and it grew more and more difficult to recover some of the markings of the stations. The primary work has, therefore, been extended to the western boundary of the State, recovering as many of the Borden points and the U. S. Coast Survey stations as possible, and thus making the scheme of primary basis of equal strength throughout the State, and leaving the points permanently marked. The results are now being computed in Washington at the Coast Survey Office, and will give us ample control of all western towns. These observations were made with a repeating theodolite belonging to the U. S. Coast Survey, with an 8-inch circle reading to five seconds. Long lines from twenty to sixty-six miles required the use of heliotropes, usually of the form commonly adopted by the Coast Survey and Army Engineers. An improvised and rougher form has been used to good advantage, being made at small expense and easy of manipulation, as described by the assistant in one of the annual reports.

The results of this primary triangulation have been very satisfactory, giving points of control within reasonable distance of one another, whose geographical positions may be computed to the required limit of precision and verified by checks incident to the method. The probable error in this work is from $\frac{1}{200000}$ to $\frac{1}{300000}$ in distance, the observed angles varying in series not over two seconds and often agreed within a second, the instrument reading to five seconds.

On taking up a new section, where the primary work has been completed, the officer in charge first provides himself with all the information that can be obtained from the archives of the State relative to the laws establishing the town lines and then obtains from the selectmen of the towns concerned copies of their latest perambulations, and confers with the selectmen in regard to them. After getting all the information obtainable the field parties go on to the ground, and perambulate one town at a time, finding successively every corner. They then ascertain, by reconnoissance of hills nearest the boundary points, what known stations or available sites for new ones will command the respective corners of boundary points, and erect signals to a proper height, say from 8 to 100 feet. The shorter signals are usually built directly on the

monument. Where a signal has to be from 50 to 100 feet high, in consequence of wooded ground, tall straight young trees are cut and spliced together. Three wire guys are then made fast to the signal pole at each place where it is spliced. A fall and block is made fast to the signal and to some suitable tree near it, and the signal is raised into place. A white band just below the flag placed at the top is then plumbed carefully over the center point of the bound and held in place by a set of guys. Observations are then made with a transit or theodolite, in sets of six angles each, forward and backward, varying the number of sets according to the size of the triangles, the least number of sets being from four to six.

Topographical sketches of town bounds are made, based on instrumental work, traverse lines being run as nearly as possible on true azimuth, to show how the point may be reached from the nearest roadway, and the necessary topographical features are located by stadia readings for distance, and the elevation of the more important points determined by means of vertical angles. This work requires the services of but two men besides the observer at the instrument.

As the boundary survey progresses the imperfect condition of the perambulation returns, and the fact of the disregard by many of the selectmen of the law in regard to marking and erecting bound marks and monuments becomes more apparent.

The commissioners' report shows that during the season of 1895, out of 151 boundary points determined, it became necessary to have 81 bounds at "corners" set under the surpervision of the field party, which were improperly marked or not marked at all.

Where the mountain ranges form the boundaries between a number of the towns, the lines following "the highest part of the mountain," it would be a very expensive and arduous task to get stone monuments of sufficient size to the summits. In such cases iron posts have been substituted. These posts consist of 2-inch iron pipes 4 feet in length, firmly fastened to the out crop of ledge and surmounted by a cast iron cap 6 inches wide, on the opposite sides of which are cast the letters of the respective towns between which the post forms a bound. The posts and caps are painted white, with the exception of the letters, which are black, and are easily distinguishable through the trees in wooded places for long distances.

ROAD STONES.

The boundary survey to the present time has been made to include all "corners" so called, *i.e.* bounds at well-defined angles. Perambulations showing angles of less than 2 or 3 degrees have

been disregarded and road stones are usually supposed to be on line. A survey and examination of the road and line stones, as they exist, was made in a few test cases, and they were found to vary from a straight line between the corners from a few feet to a hundred feet or more on one side of the other of an intended straight line. The legal value and importance of these marks seemed to call for legal opinion. The commission have, therefore, recently referred the matter to the Attorney-General, and his reply contains the following statements:

"Town boundaries can be fixed only by statute. No agreements between towns or their officers by perambulation or otherwise are effectual to alter or vary lines established by statute.

"It often happens, however, that the statutes defining town boundaries, especially the older ones, are uncertain or ambiguous. It may also happen that the line is described in general terms, and that reference must be had to facts existing at the time of the enactment of the statute to ascertain the intention of the Legislature.

"In all cases where the statute is ambiguous or uncertain, recourse may be had to other evidence for ascertaining the true line intended by the Legislature. The principal evidence so resorted to is that afforded by perambulations and bound stones or monuments. * * * * * * * * *

"Neither these perambulations nor the bound stones so provided to be erected can control or alter the bounds between towns as fixed by statute. Com. v. Heffron, 102 Mass. 151. But in cases where the true boundary is uncertain, or the words of the statute fixing the boundaries between towns is ambiguous, such perambulations and bound stones may be resorted to as evidence of the true boundary." * * * * * * *

From this opinion it seems that line stones and road stones are of greater importance than they have been formerly regarded.

Chapter 336, of the acts of 1888, was framed to provide for the definition and preservation of town boundary lines, and provides that the Commission on Topographical Survey may propose changes by straightening or otherwise in existing boundary lines, to be ratified by the Legislature, after acceptance by the towns interested. It also provides for the re-marking of angles and corners in such a manner as to establish a uniform system, as indicated by the commissioners, and makes it unlawful for any person to remove, obliterate or cover up any monument or mark so made.

Under this act several very crooked lines have been straightened and improved, reducing the number of angles to a very large degree. On one line four straight lines replaced twenty-six

courses without materially affecting the extent of territory in each town.

A whole estate in Concord is entirely surrounded by territory that belongs to Carlisle, and the boundary near by follows the irregular outline of adjoining farms.

A Boxford boundary appearing to require six or eight lines has over thirty-eight courses in the old description, varying from one to four degrees in bearing.

Many other cases could be cited to show the necessity of the straightening lines when local conditions seem to require it.

RESULTS.

Out of 353 towns and cities in the Commonwealth, 225 appear by the reports to have been wholly or partly surveyed to date, as far as the main field observations are concerned. As the personnel of the commission has changed from time to time, and the development of the work has constantly thrown new light on the condition of the lines, it is found that both the nature, extent and standard of the work required or ordered by the commission has varied; so that as the time has come for publication, all these varying conditions must, of necessity, be reduced to a uniform basis; omissions must be supplied, etc., and every fact bearing on each boundary line fully considered and weighted. Hence, in nearly all of these towns some one or more items of information have yet to be supplied, involving in many cases some slight additional field work.

Proof sheets of the new atlases are now being revised and a few towns will be published during the coming year, and the publication will be pushed as rapidly as possible, after the standard has been fully established.

A revision of the topographical atlas sheets of the Metropolitan district is contemplated by the U. S. Geological Survey in co-operation with our State Survey, and the points determined in our town boundary survey will be utilized as points of control for this adjustment. The field work for this season has already been approved and provided for.

The following authorities are recorded as connected with town boundary work of Massachusetts:

Supervisor, the late Prof. Henry L. Whiting.

Triangulation—by the United States Coast and Geodetic Survey, United States Geological Survey, Simeon Borden, Gershom Bradford, F. W. Perkins, Henry F. Walling, C. H. Van Orden, James B. Tolley, Eugene E. Peirce, E. G. Chamberlain, W. C. Hawley.

The last six gentlemen have executed the secondary and town boundary work proper. The present commissioners in charge are: Desmond FitzGerald, chairman; Prof. A. E. Burton, Frank W. Hodgdon.

General Walker summed up his opinion of town boundary work as follows:

"We believe it may be truthfully asserted that the completion of the contemplated work of determining the boundary lines of the cities and towns of Massachusetts in a manner commensurate with the scientific and accurate standard of the trigonometrical surveys already made at large cost to the State and to the United States, and which for the want of some such supplementary application to practical uses have been thus far of little value to the Commonwealth, will be the beginning and form the best basis for a cadastral (property line) survey of a state yet provided in this country."

WOODEN STAVE PIPE VS. RIVETED PIPE.

By D. C. Henny, Member Technical Society of the Pacific Coast.

[Read before the Society, November 4, 1898.*]

In enterprises requiring the use of pressure pipe, the selection of the kind of pipe to be used under the various conditions of pressure, diameter, cost of material, freight rates and accessibility constitutes one of the most difficult problems to be solved by the engineer.

To reach intelligent conclusions it is desirable that the knowledge resulting from experience be the main guide, and a discussion of the comparative merits of different classes of pipe, based upon existing works, may to some extent assist in the proper solution of this problem.

The object of this paper is to compare the two classes of pipe mentioned in the title; and, as the advantages of riveted pipe, owing to its more extended use, may be supposed to be more generally known, it is the intention more in particular to set forth the merits of stave pipe.

Instead of treating this subject in a general way, it is proposed to use a special piece of work as a basis of comparison, because this method offers the advantage of directness and concentration, while the principles involved are none the less of general application. For such common basis it is necessary to select some work or project that is generally known and that does not put either class of pipe, particularly the better known riveted pipe, at a disadvantage. In this respect the main pipe line of the Coolgardie Goldfields Water Supply is conspicuous, since the project as a whole has attracted much attention owing to its unusual magnitude, and since the chief engineer and consulting engineers united in recommending the use of riveted steel pipe (with some reservation).

For a detailed description, reference is made to the reports of Mr. C. Y. O'Connor, chief engineer, and of the Commission of Engineers consisting of Messrs. Deacon, Carruthers and Unwin; further to the editorial descriptions in *Engineering News* of February 10, February 17 and October 13, 1898.

In general, the proposition is to build a storage reservoir near

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the coast, where rainfall is sufficiently heavy, and to convey the water through a pipe line 328 miles in length to Coolgardie. The point of delivery being 1313 feet vertically above the source, a series of pumping stations was planned and so arranged as to pump the water to some high point beyond each station and cause it to flow by gravity to the next station beyond.

The capacity of the entire work was fixed at 6,000,000 U. S. gallons per day, delivered at Coolgardie, and the economical diameter of the pipe was determined to be generally 30 inches, except that a few sections were made 28½ inches, 27½ inches and 24 inches. The frictional resistance in the 30-inch pipe for the above-mentioned flow was placed at 3.103 feet per mile, the velocity being 1.888 feet per second.

The magnitude of the entire project and the relative importance of its component parts are best shown by the chief engineer's estimate:

Pumping engines and sheds	$1,000,000
Main pipe line	9,150,000
Reservoirs	1,500,000
Distributing mains	850,000
Total	$12,500,000

The scheme itself involves no new principles and is simply a multiplication of the more common arrangement of a single pumping plant and pipe line; yet, in view of its enormous cost and the peculiar climatic conditions, the Government of the Colony appointed a Commission of Engineers to report upon the material and method of manufacture of pipes, their diameter and strength and the method of protecting them, the position of the several pumping stations, the desirability and size of intermediate reservoirs and such other subjects as would result in the highest possible economy and the greatest certainty of success.

The commission performed its work with the thoroughness and skill that might have been expected from the large experience and high standing of its members. It is to be regretted, however, that, as it was essential that all improvements in recent design and practice should be fully considered, one or more American experts were not added to this board. Climatic and social conditions in Western Australia bear a much closer resemblance to those in the Western United States than to those in England, and, as these conditions are often the economical causes of striking differences in engineering practice, American experts would undoubtedly have been able to offer suggestions of the greatest value.

With the foregoing estimates before us, the great responsibility placed upon the consulting engineers can be readily understood, and they have been undoubtedly governed by a desire to combine a proper measure of conservatism with utilization of the most economical methods for conveying water under pressure. In doing so, they have considered straight and spiral riveted steel and iron pipe, so-called Ferguson's pipe,—a steel plate pipe with rivetless dovetailed longitudinal joint (see *Engineering News*, June 9, 1898),—and welded steel pipe.

Wooden stave pipe does not appear to have been considered by the commission, and the reasons for this are not entirely clear, but no doubt they have their origin in the fact that this class of pipe has so far been used neither in England nor in any of its Colonies except to some extent in Canada.

As stated before, the commission, in its "Interim Report," recommended the use of straight riveted steel pipe, although some further investigations were to be carried on with reference to the Ferguson pipe. As it is believed that, besides a large amount of riveted steel pipe, some 80 miles of Ferguson pipe have now been contracted for by the Colony, it may be presumed that these investigations were highly satisfactory, the more so because, so far as present information on the subject discloses, only about 8 miles of this pipe have heretofore been built.

It should be further stated that the commission recommended that the steel pipe be laid above ground to avoid contact with the soil, said to be strongly impregnated with alkali; that it be built in solid sections a little over one hundred feet in length anchored in the middle and resting on proper supports, and that these sections be united by expansion joints permitting the required amount of axial motion.

Having thus explained the basis upon which comparison is to be made, the author proposes to consider whether wooden stave pipe might be viewed as suitable and safe for conditions and projects similar to that described, and, if so, whether it would offer any advantages over the use of riveted pipe. The questions which present themselves in such a comparison are those respecting leakage, limiting pressure, life, carrying capacity and cost.

Leakage. This is mentioned first because of its exceptional prominence in a pipe line 328 miles in length. So far as anticipated losses from a wooden stave pipe are concerned, they may be due to two causes,—leakage proper and evaporation from its surface when exposed. For the estimation of either, measurements of

actual losses from existing pipe lines alone will give the needful information. To the writer's knowledge, there are three pipe lines upon which measurements have been made to determine the actual losses from wooden stave pipe. The first was a buried 18-inch pipe in Astoria, Oregon, in regard to which the following is stated by Mr. A. L. Adams, in his paper on the "Astoria Water Works" (Trans. Am. Soc. C. E., Vol. XXXVI., page 20).

"A test for tightness was made of the upper $2\frac{1}{2}$ miles of this pipe line after the water was first turned in. This gave results which the author believes have never been surpassed by any other pipe construction of any class. The pipe was filled from the head works, and, the gate at the lower end of the section being closed, the water rose and passed off through the overflow from the stand pipe immediately adjoining the gate. The head gate was afterwards closed. This gate was not absolutely tight, but permitted the passage of a little trickling stream, not exceeding perhaps one quart in a minute. The assistant engineer in charge of the works was much surprised on the following day to observe this same little trickling stream, apparently undiminished in quantity, passing through the waste pipe at the end of the line."

The second pipe line mentioned consists of 4.3 miles of 14-inch pipe near Los Angeles, a section of the pipe line supplying the National Soldiers' Home with water. The pipe is buried, the cover being generally 24 inches in depth. At each end of the section a concrete manhole, with cross wall and steel plate weir, permitted the measurement of the flow by means of carefully placed hook gauges; the weirs, the cross walls and the gauges being as nearly alike as possible. Three successive experiments were made, also by Mr. Adams, with flows gradually reduced in order to increase the relative importance of the leakage, in the last experiment the flow being at the rate of about 32,000 gallons per day. The first two measurements showed a slight excess of flow at the lower end over that of the upper end, probably resulting from unavoidable differences in the finish of the weir plates. In the last experiment the flow measured at both ends was, as nearly as could be measured, the same, showing the pipe to be absolutely tight. The pressure in the Astoria pipe ranged from 0 to 80 feet, the thickness of the Douglas fir staves being $1\frac{3}{8}$ inches. In the Soldiers' Home pipe the pressure varied from 0 to 65 feet, and the thickness of the redwood staves was $1\frac{1}{8}$ inches.

The third experiment mentioned was made by the author and

included the combined losses from leakage proper and from evaporation under unusually severe conditions.

A 52-inch wooden stave pipe, 968 feet in length, was built to carry the water of the Santa Ana Canal across Deep Canyon, near Redlands, California. (Trans. Am. Soc., Vol. XXXIII.; Hall, on Santa Ana Canal.) (See Photograph.) The pipe has the form of a U, with the sides inclined instead of vertical. The connecting curve has a radius of 300 feet, with its lowest point subject to a water pressure of 165 feet, and is supported by a wooden trestle 50 feet high in the middle. The pipe rests on sills, both on the mountain sides and on the trestle, and is therefore entirely exposed to the hot and dry climate of Southern California. The staves are of redwood, the finished thickness being 2 inches for pressures less than 50 feet, 2.3 inches for pressures from 50 to 100 feet, and the remainder 2.6 inches.

When, upon completion early in July, 1893, it became apparent that it would be a question of months before water could be let into the pipe through the flume, it was decided to fill the pipe by pumping in order to avoid the possibly injurious lengthwise shrinkage, after completion, of the staves, which were not thoroughly dry when put in. At the lowest point connection was accordingly made with a one-inch pipe leading up from a small pump below, which drew its supply from the creek in the canyon. Pumping continued until the creek finally dried up, the pipe being then filled to within 25 feet vertical of the ends.

The trestle, which supports only a portion of the bottom curve, had settled perceptibly as the pipe filled, and it continued to settle for some time, as was apparent from the buckling of the feed pipe, which had to be twice cut and shortened. The effect on the pipe of this settlement was that, as the pipe off the trestle could not follow the downward movement, severe longitudinal strains were induced, which were further aggravated by the breaking of some of the sills under the pipe on the trestle. These strains manifested themselves by the slight opening of the butt joints, many of which commenced to drip. Attempts were made to stop these leaks, but, so long as settling continued, leaks would persistently reappear either where stopped before or at new points. Settlement finally ceased and all leaks were permanently stopped, but this was not until after the end of the experiment. The surface of the water in the pipe, as it gradually lowered, was measured from time to time, with the following results:

Length of pipe filled in feet.	Average length of pipe filled in feet.	Length of pipe emptied in feet.	Time in hours.	LOSS U. S. gallons.	U. S. gallons per day.	U. S. gallons per day per sq. foot exterior surface.	Average pressure at bottom in feet during experiment.
800							
715	757.5	85	231	9384	975	0.086	132
702.1	708 5	12 9	57	1419	597	0.057	123
682.9	692 5	19.2	93	2120	547	0.053	120

It was impracticable to determine separately the losses from dripping leaks and from evaporation, although it may be assumed that a large portion of the loss, as last measured, was due to evaporation both from the water surface at the open ends and from the surface of the pipe. There would be nothing surprising in this, considering the prevailing temperature of the air and of the stagnant water in the pipe, the permanent sunshine throughout the day and the frequent hot winds blowing up or down the canyon.

While it is admitted that the results are not conclusive, they point to the probability of losses from evaporation, that may become serious in very long pipe lines exposed from end to end. So far as they go, the measurements may be valuable as establishing a maximum value for all losses under conditions as described.

Whether asphalt or paint can be made to adhere to the outside of the pipe, and whether a coating would materially reduce the losses from evaporation, are subjects in regard to which there exists difference of opinion among engineers, and which cannot be settled except by trial. The author knows of only one line of pipe that is exposed and coated on the outside, and when he had occasion to examine it, after about four years' service, he found the asphalt coating in bad condition and practically offering no protection at all. Whether this was because the coating was driven off by the water pressure, or because the asphaltum had not been of the proper consistency, he had no means of determining, but he is inclined to believe that the first-mentioned cause is liable to prevent firm adherence and effective protection.

The exterior surface of 328 miles of 30-inch pipe would, in round numbers, amount to 15,000,000 square feet, and, if the daily evaporation from its surface should reach 0.05 gallons per square foot, the entire daily loss would be 750,000 gallons; on the other hand, the first two experiments mentioned indicate that the loss from a buried wooden pipe, even if 328 miles in length, would be very small, provided it be well designed and carefully constructed.

Measurements of the loss from riveted steel pipe have not come to the author's knowledge, nor is it stated in the report of the commission how the estimate of 5 per cent., or 300,000 gallons

per day, which includes losses from the intermediate reservoirs, has been arrived at. Why it has been expressed in percentage of total flow is not clear, as there is no connection between the velocity and the leakage.

One of the arguments in favor of laying the pipe on the surface was that leakage could be more readily found. This may be true in the case of very open, gravelly soils, but in ordinary ground it has been the author's experience that even exceedingly small leaks will make themselves apparent if the pipe is buried at ordinary depths, which is in part borne out by the records of the Astoria and Los Angeles pipes mentioned.

Limiting Pressure. The pressure which wooden stave pipe can be made to withstand safely depends upon the hardness of the saturated wood, and a working pressure of 200 feet is considered by the author and shown by experience to be a safe practical limit in the case of redwood and Douglas fir, for reasons which it is beyond the scope of the present paper to discuss. If the staves are carefully selected, there will be no loss from percolation through the wood at the highest pressure when the pipe is buried.

The Coolgardie line, as now located, contains 255 miles, or about 80 per cent. of the total, on which the maximum pressure is 200 feet or less. These pressures are based on the grade lines as determined and laid down by the commission for steel pipe. The lightest gauge to be used is intended for pressures from 0 to 220 feet (for 30-inch pipe), and there was therefore no object in so locating the pipe as to reduce the pressure within these limits, which explains why, with a few exceptions, the location of the line simply parallels the railroad from Fremantle to Coolgardie. Easy accessibility, especially in an uninhabited country, is unquestionably a great advantage, but is not essential, and when stave pipe is under consideration it is customary to be governed, in making location, by the comparative cost per foot of pipe under various pressures. The practical result is generally an economical compromise between an excessively long contour line and a straight line, with heavy pressures. Such a course leads to increased length for the sake of economy, and, in a case like that at Coolgardie, it would also have the effect of greatly reducing the amount of pipe upon which the pressure would exceed the limitation set for stave pipe construction.

As to steel riveted pipe, the safe limit of pressure under which it can be built is undoubtedly much higher than the highest pressure on the Coolgardie line.

The commission recommended that the strength of the pipe be determined from hydrostatic pressure, with the exception of the section between the second and third pumping stations. This recommendation was based on the ground that the advantages of stop valves at regular intervals along the line were considered so great as to outweigh the great extra cost involved in making the pipe strong enough to stand the full head of water when at rest in the main. The section between the second and third pumping stations, excepted by the commission from this general recommendation, has been left subject to pressures from hydraulic grade only. This was done because the method followed for the other sections would have increased the already high pressures, some 200 feet, on about 36 miles of pipe, and it was therefore recommended that a reservoir be built at one of the intermediate summits. No reason was given why, since any small reservoir, basin or even stand pipe, placed at hydraulic grade just upstream from a main gate, will give relief and protection against increase of pressure over that due to hydraulic grade, this method was not followed on the other sections at least in part. With such overflows placed at every point where the pipe line approaches hydraulic grade, even assuming the distance between such points to exceed the desired standard distance between main gates, the pipe line would be divided up into sections, the maximum pressure upon which would be measured by the elevation below that of the nearest overflow upstream. It cannot be believed that the temporary waste of water at the points of overflow would present any serious obstacle. Moreover, it may be presumed that a telephone line will parallel the pipe line, so that it will be generally possible, if so desired, to have the pumps at the head of the section stopped before any gate is closed.

This matter is touched upon here because, with stave pipe, the close relation between cost and pressure renders any inexpensive method of reducing even moderate pressures highly desirable, and it is for this reason that most wooden stave pipe lines now in use have been carefully protected from unnecessary pressures. In case waste of water cannot be tolerated, the same object can in part be attained by the construction, at each summit, of a small basin into which the pipe discharges through a balanced valve operated by a drum float. The section of pipe down stream from this basin cannot be subjected to any pressure greater than that due to the depth below high water in the basin, for, even should the balanced gate fail to act, the basin would then overflow. This simple and inexpensive arrangement reduces the maximum pressure by steps,

and has been successfully applied to the 14-inch wooden stave pipe near Los Angeles already quoted.

Life. At the outset it will be necessary to distinguish the two cases of pipe buried and pipe exposed. When exposed, the steel bands of a stave pipe can be constantly inspected and repainted whenever deemed necessary, and the life of this portion of the pipe may be considered sufficiently long to satisfy all requirements. As to the staves, it must be evident that changes of temperature and wind will cause a steady movement back and forth of the limit of saturation within the staves, thus leaving the outer skin of the wood in a condition where it would eventually decay. This decay need not necessarily result in the loosening of the bands, as the wood under the bands would be protected from evaporation; yet it would finally reach a depth where there is a permanent saturation, with a consequent steady increase of the losses from evaporation. Uncertainty as to the effect of a coating of asphalt or paint applies to this subject as well as to that of losses from evaporation.

There are short trunk lines for power purposes in the New England States, which, though built of pine, exposed, and, moreover, at times running but partly full, have seen from 20 to 40 years of service and are still in use, and from sound redwood better results might be expected. The general practice, however, is to bury the pipe, except where, owing to rocky formation or necessity of placing pipe on a trestle or bridge, such course is impracticable, and then the pipe has generally been boxed in.

When buried, the conditions determining the life of the stave pipe are reversed. Supposing the pipe to be filled at all times,—a vital condition to be strictly adhered to,—the staves will remain permanently water-soaked for their full thickness and no decay can take place. But the steel bolts and iron couplings will then be in contact with the soil; nor will it be practicable to re-coat them. Hence the endurance of the pipe will then be measured by that of the metal, and will be, to a great extent, dependent upon the protective coating and the character of the soil. On this important subject experience has not been sufficiently long to warrant any definite estimate, and only general conclusions can be drawn. It is important in this connection to disabuse the mind from considering the life of steel pipe as in any way furnishing evidence on this point, for the cases are by no means parallel. The life of an iron or steel pipe is not limited by any consideration of weakened strength resulting from corrosion, but rather by the peculiar pitting action to which the plates are subject. The result is that leaks occur in some places, while at others the plate is yet perfect, and

the constant recurrence of leaks finally forces abandonment of the pipe when the actual percentage of metal lost by corrosion is very small. Were it practicable to line with wooden staves the inside of a completely worn out metal pipe, a serviceable pipe would be obtained, promising long life, and the steel would not be strained up to its limit of strength until about 75 per cent. of the metal had rusted away. This is the condition of the wooden pipe, with the important exception that the metal on the outside of the pipe does not occur in a form exposing a relatively very large surface to corrosive influences as with plate; but, on the contrary, in a condensed form, the round section of the bolt presenting a minimum of surface to contact with the soil.

A forcible illustration of this difference was furnished on a compound wooden and riveted steel pipe line built in the spring of 1896, for the Hollister (California) Water Company. In the fall of 1897 a portion of the steel pipe, after having required an ever-increasing expense for repairing leakage through pit holes in the plate (No. 14 B. W. G.) had to be replaced, and, as this portion was near a point of junction of wooden and steel pipe, and the pressure presented no obstacle, it was decided to extend the wooden pipe and connect with the steel pipe beyond where the trouble occurred. The soil in which the wooden and the steel pipe had been buried was adobe, and, so far as could be judged, was identical for both kinds of pipe. The corrosion of the steel pipe seemed to have proceeded mainly from the outside, and it therefore became a matter of interest to note the condition of the steel bands on the wooden pipe. It was found that the asphalt coating had deteriorated, but the metal under it showed hardly any sign of corrosion, and the nuts could easily be turned on the threads. Other portions of the steel pipe (some of it No. 12 gauge) have since been replaced by cast iron pipe; while, on the contrary, the wooden pipe is, so far as known, in practically the same condition as when first laid.

The oldest continuous stave pipe of any magnitude was built by Mr. J. T. Fanning, in 1874, for the Manchester, N. H., Water Works. (See Trans. Am. Soc., March, 1877.) The pipe is 72 inches in diameter, banded with $\frac{1}{2}$ x $2\frac{1}{2}$-inch flat iron hoops and is buried. It has been in constant use, has required no repairs and is stated to be in good condition so far as known.

After carefully weighing all evidence on both sides of this question, the author concludes that, even assuming the presence of alkali in the soil, a longer life is insured—supposing the bands

to be thoroughly coated—when the wooden pipe is buried than when left exposed.

As to riveted pipe, it is, as a rule, buried; the only exceptions which occur to the author being where the pipe had to be frequently moved, as in hydraulic mining and dredging, and occasional short stretches, where special conditions intervene. The life of buried steel pipe is very uncertain. In many cases even light gauge pipe has lasted remarkably well; in others it has had to be abandoned in a very short time, as in the case of Hollister above cited.

Of numerous instances, one more may be quoted, showing the short life of light steel pipe laid in alkali soil. Echo Lake and West Lake, forming part of the irrigation system of the city of Los Angeles, are connected by pressure pipe. Originally a 20-inch No. 16 B. W. G. steel pipe was used, about one mile of which had to be abandoned at the end of three years, after considerable expense had been incurred in stopping leaks, which were all the more annoying because of the pipe's location near the center of the city. A No. 14 B. W. G. steel pipe was then laid, which lasted four years, and in the spring of 1895 was replaced by wooden stave pipe.

The lightest gauge for the Coolgardie steel pipe recommended by the experts is 3-16 inch, and, as previously stated, it is proposed to lay this pipe on the surface in order to lessen the danger from corrosion and to facilitate the detection of leaks. A double asphalt coating is specified, all of which may fairly be expected to insure long life for the pipe proper. While the gain in the life of the pipe, in being kept from contact with the soil, cannot be questioned, it may be asked whether this is not too dearly paid for by the necessity of providing and maintaining an enormous number of expansion joints, unless indeed some type of joint can be devised which does not depend for its tightness on rubber or other elastic material promising but a short life under severe climatic conditions and which can be repacked without interrupting the flow in the pipe.

It is interesting to note here that the much discussed question of comparative endurance of steel and iron is disposed of by the commission with the statement that they see no reason for preferring one to the other.

Carrying Capacity. It is to be regretted that the number of experiments for the determination of the carrying capacity of wooden stave pipe are as yet very limited. The following is believed to contain all direct knowledge on the subject:

EXPERIMENTS ON FLOW THROUGH WOODEN STAVE PIPE.

Authority.	Locality.	Year.	Diameter in Inches.	Length in Feet.	Fall per 1000.	Observed Velocity Feet per Sec.	Coefficient "C" Chezy Formula.	Coefficient "n" Kutter Formula.
Adams	Los Angeles	1898	14.11	4403	.145	.691	105	.0106
			14.075	3436	.161	.695	101	.0109
			14.05	4825	.170	.698	99	0111
			14.05	8931	.178	.751	104	.0108
			14.05	9912	.391	1.167	109	.0107
			14.05	8931	.375	1.181	113	.0105
			14 05	9912	.638	1.53	112	.0108
Adams	Astoria	1896	18	23,318	1.9628	3.605	133	.0099
Schuyler	Denver	1891	30	....	....	....	....	.0096
Marx, Wing and Hoskins	Ogden	1897	72.50	2710	.0952	1.242	104	.0148
				2710	.181	1.876	114	0139
				2710	.331	2.689	120	0134
				2710	.517	3.453	124	.0131

It may be said in addition that some measurements were made in 1892 by the author to determine values for "C" and "n" on a line of 24-inch stave pipe at Butte, Mont., 18,389 feet in length, that for a velocity of 1.147 feet per second the value of "C" was found to be 127, corresponding to a value for "n" of 0.0103, but that he hesitates to attach great weight to this result, as the only method at hand to determine the flow was from frequent determination of velocity by means of vertical floats in a semicircular flume at the upper end of the pipe. This method was liable to considerable error.

The author has generally made use of the Kutter formula for computing the capacity of wooden stave pipe. He was led thereto by the consideration that experiments on new cast iron pipe show this formula to give fairly constant values for "n" under greatly varying conditions of flow and diameter, and that wooden stave pipe offers, in this respect, a nearer resemblance to new cast iron than any other kind of pipe on which a wide range of measurements is available, although it may be assumed to have a smoother interior surface. The value of "n" applicable to new cast iron pipe was found to be 0.011, 48-inch pipe being the largest size experimented on. The variations from this value are irregular and seem to point rather to probable differences in surface finish and errors in measurement than to incorrectness of the formula itself.

For wooden pipe the author assumed a value for "n" = 0.010,

because in open channels, lined with smooth planed boards, smaller values had been found, and because this assumption has been corroborated by experiments on 30-inch pipe made in Denver, Col. (Trans. Am. Soc. C. E., Vol. XXXI.) It is further confirmed by the experiment at Butte on 24-inch made in 1892, and again by the Astoria experiments on 18-inch pipe made in 1896.

The Ogden experiments were made last year and the results are unquestionably unexpected. It is beyond the scope of this paper to consider in detail whether some unusual conditions did not exist which may have contributed to the results, and it is sincerely hoped that the experimenters will still further put the profession under obligation by carrying out their intention to extend the range of their experiments and thus throw further light upon this subject.

The latest experiments on wooden stave pipe were made on a 14-inch pipe at Los Angeles by Mr. A. L. Adams. As will be noted from the table, they are with rather low velocities and give values for "n" between 0.0105 and 0.0111.

From the foregoing the author concludes that for diameters from 24 to 30 inches a value of 0.010 for "n" may be fairly expected. He wishes to emphasize, however, that from a commercial point of view it seems essential at times to provide a reasonable margin of safety in estimating the required diameter of a pipe line; for instance, where delivery of a stipulated quantity of water is contracted for and where the attainment of even a slightly smaller flow might entail serious consequences, or, as in a case like that of Coolgardie, where the pipe line interlocks with expensive machinery designed to pump and give greatest efficiency for a certain predetermined flow. Should this flow not be attained there would be clearly waste in first cost of pumps and possibly also in subsequent cost of pumping. Hence in such cases the size of the pipe should be based upon what it is reasonably certain to carry, rather than upon what it may carry, and, in using a value of "n" = .011 for 30-inch wooden pipe with low velocities, as in Coolgardie, it is believed that an ample but not excessive margin of safety is provided. From this a value of "C" = 128 would result and a frictional resistance of 1.838 feet per mile. A most important fact in this connection is that, so far as known, the interior surface of wooden stave pipe does not become rougher with age. The author has heard the possibility advanced of a vegetable growth starting on the interior surface of the pipe, which would impede the flow, but, so far as known, no such growth has yet been observed in pipes after many years of service. Nor has the author ever heard of any

growth in the interior of bored wooden pipe, of which hundreds of miles have been in use. He has been informed of roots growing into a wooden pipe, but that was under conditions where the vital requirement that it be kept full of water had not been observed, but where, on the contrary, the pipe had never run full, and where originally careless construction and insufficient back-cinching had permitted the wood to shrink and the seam joints to open. Such growth had not been from the interior, but had penetrated from the outside through the open top seams, in search of moisture, as has been often similarly noticed in open jointed drain and sewer pipe.

It is believed that experience does not warrant any apprehension in this direction, but rather that it indicates that wooden pipe, if properly used, will retain its original carrying capacity for an indefinite time.

The experiments on new riveted steel pipe now available tend to show that the Kutter formula does not apply to such pipe. The more simple Chezy formula, however, gives fairly satisfactory results, at least for velocities of $2\frac{1}{2}$ feet per second and higher, when the value of "C" can be uniformly taken at 110. For lower velocities the value of "C" ranges within rather wide limits. While for a velocity of 1.5 feet per second the value of "C" in the 72-inch Ogden pipe was 111, it was found to be 91 in the 36-inch pipe of the East Jersey Water Company, and, for the same velocity, intermediate values have been found for intermediate sizes.

The foregoing refers to new pipe only. Experiments with pipe which has been in use several years show a decided decrease of capacity. For instance, a 48-inch pipe of the East Jersey Water Company gave a value of "C" = 106 when new, and = 85 when four years old, for 1.5 feet per second velocity. For practically the same velocity the value of "C" in the 36-inch pipe at Rochester, when 14 years old, was found to be 80, and, for a velocity of 3.3 feet per second, the 24-inch pipe at Rochester, of equal size, gave a value of "C" = 78.

The Commission of Engineers, in estimating the required diameter for the Coolgardie steel pipe, placed the value of "C" at 98. In the light of the above-mentioned experiments it seems doubtful whether sufficient allowance has been made for probable deterioration by tuberculation. If it be conceded that in the course of time the value of "C" may fall below 98, the desired flow of 6,000,000 gallons daily can no longer be maintained even by increasing the pumping pressure, as the pump mains proper constitute but the first and smaller portion of each section of pipe be-

tween stations, the remainder being gravity pipe laid with summits near hydraulic grade.

Assuming, for the values of "C", for 30-inch stave pipe, 128, as deduced above, and for 30-inch riveted pipe, 98, as adopted by the commission for the Coolgardie main, the respective frictional losses for a velocity of 1.888 feet per second would be 1.838 feet and 3.103 feet per mile, a difference of 1.265 feet per mile in favor of wood or 415 feet for a line 328 miles in length. The total pumping head, in the case of Coolgardie, was stated to be 2605 feet, and a decrease of 415 feet would mean a reduction equal to 16 per cent. In justice to riveted pipe it should be stated that the above comparison would hold good only in case the wooden pipe were buried by reason of the necessity of providing for losses from evaporation, which would materially change the results. For independent reasons elsewhere stated, the author believes, however, that wooden pipe should be buried whenever possible.

Cost. Considerations of effect of pressure on cost, limiting pressure and differences in frictional losses make it essential that location should be made with special reference to the kind of pipe to be considered. It would obviously lead to erroneous results to make the location best suited to one kind of pipe the basis for an estimate of another kind of pipe.

In order to bring out the economical possibilities of wooden stave pipe it may be stated that the author finds that under conditions as regards freight rates, etc., similar to those stated in the chief engineer's report as applying to the Coolgardie main pipe line, the cost of 30-inch redwood stave pipe, laid and buried, may be estimated at $1.70 per foot for pressures less than 20 feet, increasing gradually with the pressure to $3.90 per foot for 200 feet pressure. The cost of the steel pipe was estimated by the chief engineer at $5.29 throughout for all sizes and weights and inclusive of fixtures.

What would be the resulting economy in the use of wooden stave pipe for a portion or all of a pipe line like that at Coolgardie is a question upon which the author, for the reasons given, does not wish to venture. It may be stated, however, that while it is true that a stave pipe location generally shows a greater length of line than that for steel pipe, such additional length would result from economical consideration only, and would be the cause of a reduction rather than an increase of total cost.

In a case where water is to be pumped, the cost of main pipe line is not the only point to be considered. If, owing to lesser friction in stave pipe, the total pumping head be reduced, a reduc-

tion in the first cost of pumping machinery would result, and a corresponding reduction would follow in the annual cost of pumping, which, in the Coolgardie case, is estimated by the chief engineer at over half a million dollars. Should, in a similar case, a saving of 16 per cent. in these items result, as was estimated, it is evident that there might be substantial economy in the use of stave pipe, even at a greater cost per foot than riveted pipe.

DISCUSSION.

Mr. Allardt.—In Honolulu we have an insect called the bumblebee, that bores into the wood in houses, making holes almost as large as my thumb. Would a wooden pipe be subject to such attack by the bumblebee or other insects or vermin? Is there any danger of a rodent working into a pipe in search of water, say a ground squirrel or gopher?

Mr. Stut.—Some time ago I met Mr. Henny on the Oakland boat, and we were comparing steel and wooden pipe, and discussing the question as to which would last the longer, and I put the question as to why steel pipe should be used in place of iron pipe, when the former was eaten out so quickly. My idea is, in the case of steel, that it is eaten away by the action of electrolysis. Now, in steel the presence of two elements, iron and carbon, is favorable to galvanic action. Inside of the pipe we have water, and on the outside we have alkali. We know that if iron and carbon be dipped in water, or in any saline solution, an electric current will be formed, and this will affect the steel; we get an electro-chemical element that goes on day and night, and in a very short time the steel is eaten up. With iron, which is practically free of carbon, this will not be the case. In Australia, if the pipe were buried in the ground, I think iron rather than steel should be used.

If I place in water a small piece of carbon and a small piece of iron, a current of electricity will be formed; the current will go from one to the other and the material will be eaten up. As to the eating away of steel pipe, I think this is the only true explanation that will hold good. I have had a good deal of experience in sugar factories. In one we have an iron tank about 16 feet high and 5 feet in diameter. As the sugar is melted it runs through bone coal. The inside of the tank is painted with the best kind of metal paint. The iron is apparently well protected, but in a very short time the solution of the sugar gets behind the paint and eats the iron. In handling coated pipe, the coating gets knocked away or cut into in places, which are thus left open to attack.

CHAIRMAN MARX.—Such a coating would not be protective.

MR. STUT.—Only to a certain extent. Some years ago, in a sugar factory, we had a large pan lined inside with big copper coils, into which steam was turned to drive the vapor off from the sugar. There was a fixed cast iron arm and pipes connected with the pan, and a clamp was used to hold them in position. The clamp broke, and, not having anything else, a big copper wire was used to perform the service of the clamp. When we next opened the pan, we found the copper had a large groove in it as though it had been cut with a saw. That was the result of electric action. The combination made a sort of galvanic battery.

MR. ALLARDT.—If the iron or steel pipe is in a trench in alkali soil, but the pipe is surrounded with a layer of sand, and this sand becomes wet, either from leakage of the pipe or from rain, will the alkali on the outside extend to the pipe and produce this electric action?

MR. STUT.—It would, no doubt, in the case of steel. With iron there would be less trouble. I should always use iron in preference. In the case of wooden pipe there is the wood, and the steel hoops around the wood, and the steel would not come in contact with the water inside the pipe. That would be different from the case where the entire pipe was of iron or steel, which has water on one side and the alkali on the other. It is well known that the slightest current must produce chemical action.

MR. NORBOE.—In regard to the bumblebee that Mr. Allardt mentioned, I presume most of you are aware that we have a bumblebee in California that bores into wood. I have seen cedar so honeycombed by them that it looked a good deal like a pile eaten by the teredo.

The question why steel should be used in preference to iron in pipes is to some extent a matter of cost. The pipes are calculated to resist a certain pressure, and the greater tensile strength of the steel is certainly a factor in causing its selection over iron; because, to resist the same pressure, we should require much heavier material, and the extra cost of transportation would also cut quite a figure.

I have never had much actual experience with wooden pipe, but I have investigated it pretty thoroughly, and I believe that in many places where it is not now used it can be used with greater economy than any other material.

MR. HOSKINS.—Mr. Henny has certainly made a plausible showing in favor of most of the points he has brought forward in regard to wooden pipe. I cannot quite agree to all he says upon

the question of capacity. Upon this question his reasoning does not appear to be altogether safe when applied to pipes of large sizes.

The amount of evidence available regarding the carrying capacity of wooden pipes is very small indeed. Experiments have been made upon a 14-inch and an 18-inch pipe, both apparently fairly reliable; also with a 24-inch pipe, admitted to be of uncertain value; and with a 30-inch pipe, regarding which data are lacking from which to judge of the accurary of the results. Then there are the experiments upon the 72-inch pipe at Ogden. These are the only ones to which I have found any reference.

The only published reference to the experiment on the 30-inch pipe is contained in the paper by Mr. Schuyler, in the Transactions of the American Society of Civil Engineers, and it is there treated in two or three sentences. It is stated that the discharge was determined by two methods,—by measuring the depth added to the reservoir in a given time, and by measuring the velocity with a current meter at a manhole in a tunnel. As a result it was found safe to use the Kutter formula with "n" = 0.010. Upon this brief statement it appears unsafe to attach much weight to this test, in the entire absence of corroborative evidence regarding pipes above 18 inches in diameter.

In order to bring out clearly the nature and value of the evidence now available regarding the capacity of stave pipe, it is instructive to consider the growth of our knowledge regarding the capacity of riveted steel and iron pipes. At present there is a considerable amount of experimental knowledge regarding the capacity of riveted pipes. But experiments on the larger sizes came much later than on smaller sizes, and it was found wholly unsafe to apply to pipes upwards of 3 feet in diameter the values of the Kutter coefficient found for smaller ones. My colleagues and myself, in the paper describing the Ogden experiments, have tabulated all data known to us regarding the capacity of riveted pipes. Of the experiments on pipes smaller than 36 inches in diameter, nine (diameters ranging from 11 inches to 35 inches) gave "n" equal to 0.010 or 0.011, while not a single experiment on a pipe which was new or probably as smooth as when new gave a value of "n" greater than 0.011. If no experiments had been made on pipes of larger size, doubtless many engineers would advocate the use of Kutter's formula for riveted pipes of all sizes up to 48 inches, or even 72 inches, with "n" = 0.011 for all sizes. That such a procedure would be wholly unsafe is shown by the fact that experiments on new riveted pipes of diameters from 36 inches to 72

inches have in nine cases given values of "n" ranging, for average velocities, from 0.013 to 0.014, while in no case has a less value been found. It would seem that there is at least a possibility that those engineers who assume that Kutter's formula, with "n" = 0.010, may safely be applied to wooden pipes of all sizes are erring in somewhat the same way in which many erred in the case of large riveted pipe before reliable experimental data regarding the larger sizes had been made public.

I have thus far said nothing in regard to the results given by the Ogden experiments. Mr. A. L. Adams, in his paper before the American Society of Civil Engineers (September, 1898), has disregarded those results because they did not agree with the results found for pipes of smaller sizes on the basis of Kutter's formula. Without desiring to magnify the importance of the Ogden results, I may express the opinion that experiments on pipes 14 inches, 18 inches and 30 inches in diameter, however reliable, can furnish no justification for the rejection of an experiment on a 72-inch pipe. To do this because Kutter's formula requires it seems to me to give undue authority to that formula. It surely cannot be assumed, apart from experimental knowledge, that Kutter's formula is applicable to wooden pipes of all sizes; yet here the formula is appealed to as the sole justification for rejecting a series of experiments on a pipe of diameter more than double that of any other whose capacity has been measured.

The Ogden experiments do not stand alone in discrediting Kutter's formula as a safe guide in the design of large pipes when accurate knowledge of the discharging capacity is required. The coefficient "n," which is assumed to depend only upon the nature of the surface, has been found to vary both with the diameter and with the velocity of flow. The variation with velocity has been pointed out by several writers. In the Ogden experiments on the steel pipe "n" was found to increase with increasing velocity, while in case of the wooden pipe "n" decreased with increasing velocity. In the experiments with the 14-inch stave pipe at Los Angeles, Mr. Adams found "n" greater than 0.010, but in the few gaugings made (all at low velocities), a tendency was observed for "n" to decrease as the velocity increased, and it was only by assuming such a change in "n" that these tests were brought into conformity with the Astoria test on 18-inch pipe.

The question of capacity is not the governing element in all cases, but in many cases it is important. The difference between the capacity as estimated by Kutter's formula with "n" = 0.010 and that indicated by the Ogden results is so great as to materially

influence the design when the capacity needs to be carefully considered. The "C" in the Chezy formula, for 72-inch pipe, assuming the Kutter coefficient to have the value used by Mr. Adams and Mr. Henny, would equal about 163 for a velocity of 3 or 4 feet per second, while the value found in the Ogden experiments for similar velocities was about 125. The difference between these values is very material indeed.

In estimating the weight to be given to the Ogden results as a guide to future design, it should be noticed that the pipe experimented upon was curved for a considerable part of its length, and that this curvature doubtless influenced the loss of head. How great this influence would be we have no means of estimating. But if the curvature of the pipe is an important element affecting our results, it is also important in most practical cases, and should receive far more attention than is usually accorded to it in estimates of carrying capacity. I do not think the curves in the Ogden pipe are exceptionally sharp in comparison with what is usually considered allowable.

The riveted pipe experiments quoted by Mr. Henny are mostly for low velocities, in accordance with his special basis of comparison. It should be borne in mind that the probable error in a value of "C" determined from an experiment is great in proportion as the velocity is small. Judging from our experience at Ogden, where our velocities ranged from 0.5 feet per second to about 3.8 feet per second, I should be inclined to give little weight to a single determination of "C" at a velocity less than about 1.5 feet per second. Of course by multiplying the number of observations a reliable mean result may be reached for a velocity as low as 1 foot per second.

Mr. Allardt.—It seems to me that as to the relative discharging capacity of wooden stave pipe and steel pipe, we must decide in favor of the wooden pipe, from the fact that it has a smooth inner surface, while steel pipe has a rough surface on account of the rivets and laps. So the discharge of a wooden pipe of the same diameter must necessarily be greater than that of a riveted pipe.

Mr. Marx.—That question has not been raised. There is no doubt in the minds of Mr. Henny and Mr. Hoskins that the carrying capacity of a wooden stave pipe is larger than that of riveted pipe of the same diameter. It is simply a question of whether or not the Kutter formula, with "n" = 0.010, can be safely applied in calculating the carrying capacity of wooden pipe—whether there has been sufficient experiment to prove it. Mr. Hoskins and some others take issue on this point.

Mr. Henny.—The question of rodents injuring stave pipe has been frequently raised. The stave pipe supplying Butte, Montana, passes through ground honeycombed in places by prairie dogs, which, however, have never disturbed it. There are a great many gophers around Denver, where stave pipe has been buried for fifteen years, and we have yet to hear of a gopher having eaten into the pipe. They do not seem to like it.

As to ants, we had some experience in Los Angeles. Staves were piled up along the line. In one place they were laid in brush on the hillside, and there it was observed, when pipe building commenced, that ants had eaten into the staves, making small holes never over $\frac{3}{8}$ inch in depth. The ants were always found in pairs in these holes and may have bored in to deposit their eggs. That portion of the line has been carefully watched, but no further evidence of their existence has been discovered. A number of these ants were laid before Dr. Behr, of the Academy of Science, who pronounced them to belong to the same family as the white ant of Central America. He said similar ants had attacked wooden sidewalks in this city. It is the author's belief that while they may eat into dry or partly dry wood, they will not attack wood that is thoroughly saturated. If they require air for life, they cannot live in a saturated stave. In the Santa Ana pipe, which is exposed, the wood may dry out possibly a quarter of an inch at times, and an ant or a bumblebee might eat into it to that depth, but at night the moisture would come to the outside. So it is not likely their work would be injurious. No attack from bumblebees or ants has so far been observed in either the three lines of 52-inch pipe of the Bear Valley Irrigation Co., which have now been in over 3 years, or an older 48-inch pipe, which has been in 8 years, all exposed.

In regard to the particular point Mr. Allardt has raised as to the comparative carrying capacity of wooden and steel pipe, my recollection is that, so far as the Ogden experiments are concerned, the value of "C," instead of being 163, was 125 or a little higher, while in steel pipe of the same diameter it was 110. Those experiments gave the wooden pipe about 13 per cent. the advantage.

In answer to what Mr. Hoskins has said in regard to the Ogden experiments affecting the applicability of the Kutter formula to stave pipe, it may be here repeated that the author's use of the Kutter formula was based not so much on the few experiments on stave pipe, but rather on the fairly satisfactory results obtained with new cast iron pipe, and the similarity in character of interior surface was noted so far as absence of rivet heads, laps or other obstructions are concerned, with the stave pipe

having the advantage in point of smoothness. When practically the same value of "n" is found for a 6-inch as for a 48-inch new cast iron pipe, for a fair range of velocities, without startling differences for intermediate diameters, it may be concluded that the Kutter formula is applicable to new cast iron pipe, and, by inference, to other pipes with unobstructed section, within the range of the experiments. Beyond this range estimation becomes necessarily to some extent speculation, until further information be obtained, such as the Ogden experiments. Then, if this new information differ greatly from what was inferred from previous knowledge, it is closely scrutinized and the weight to be accorded it must remain a matter of personal judgment. The Ogden experiments would incline the author to greater conservatism in estimating the capacity of large stave pipes.

Darcy's experiments, with semicircular channels running full, are considered by the author to throw some valuable side light on the question, especially those with channels of large diameter. A channel 49.2 inches in diameter, lined with pure cement, gave a value for "n" = 0.0102; another, lined with mortar containing two-thirds cement and one-third fine sand, gave "n" = 0.0109, and another, 54.1 inches in diameter, lined with partly planed boards, gave "n" = 0.0118. In all these cases the depth of water equaled the radius, the values for "n" practically remaining the same for all depths.

As well-planed wood compares favorably with pure cement in smoothness, the Darcy experiment, first quoted, seems to confirm the inference that a value of "n" = 0.010 may be used for wooden stave pipe up to diameters of 48 inches, leaving out of consideration additional friction that may be caused by short bends or great percentage of sweeping curvature.

The latter will in some way have to be estimated (or, as the case now stands, guessed at) separately.

It is very desirable that the range of the Ogden experiments be extended. So far as they have gone, the trend is towards an increase of the value of "n" as the velocities increase. Additional experiments are bound to throw further light upon this subject, and, in a measure, to be a check upon the data now at hand.

Mr. Marx.—I will state, for the information of Mr. Henny and the members of the Society, that, since these experiments were made at Ogden, a temporary dam has been built which raises the level of the river some ten feet. It will therefore be possible to extend the range of experiments to velocities higher than those previously experimented on by us, and arrangements have already been made for doing so.

Mr. Hoskins.—Mr. Henny has referred to experiments on semicircular open conduits as bearing on the question of capacity. It has been assumed by writers on hydraulics that circular conduits flowing half full have the same values of "C" and of "n" as when flowing full, the hydraulic radius having the same value in the two cases. But this has been regarded only as a rough approximation, which is used in the absence of better knowledge. In some respects the semicircular section resembles the circular, and in other respects they are not the same. The assumption that the influence of the form of the cross-section upon the rate of discharge is wholly accounted for in the value of the hydraulic radius is a deduction from a theory acknowledged to be defective, and is not borne out by such experimental knowledge as we have, except in a very rough way. We have very little definite knowledge regarding the distribution of velocity throughout a cross-section.

The Kutter formula is an ambitious formula. It was designed by its inventors to apply to open channels of all sizes and forms. As used by certain writers, it is still more ambitious, assuming to give a rule for computing the discharge of any stream from a half-inch pipe up to the Mississippi River or the Amazon. The experiments upon which it is based justify us in accepting it as a good formula for certain classes of channels,—good because no better means of estimating discharge are available, but not to be expected to give results of great accuracy. But the experimental basis does not include much in the way of pipes above the smaller sizes, and it would be strange indeed if the formula, with a constant value of "n" for all diameters, should give very accurate results upon large pipes. Of the data available, I think the majority is rather against the formula than in its favor, for pipes above 3 feet in diameter. This is certainly true of riveted pipes, as I have already shown. It is asserted that experiments on smooth conduits show closer agreement with the formula; but for pipes of large sizes I think the evidence is too limited to warrant such a conclusion. The experiments of Fitzgerald on 48-inch smooth cast iron pipe agree well with the formula, showing a nearly constant value of "n," with varying velocity. But the only other experiment upon a smooth cast iron pipe as large as 4 feet in diameter which I have seen recorded gives a much smaller capacity than was found by Fitzgerald and by Stearns. Of the available data much is of uncertain value. In many cases probably a high degree of accuracy in the measurements was not attempted. The methods of measurement employed have not always been such as to insure results of a high degree of reliability. A weir will not give

good results unless constructed and used with the greatest care. A reservoir measurement is liable to errors due to evaporation and leakage, in addition to observational errors, which can be eliminated only by the greatest care. The majority of the available data are based upon measurements made by these methods, and in many cases it is uncertain whether proper precautions have been observed.

In view of these facts and of all the evidence, I think we are justified in questioning the applicability of Kutter's formula to circular pipes, with a constant value of "n" for a given kind of surface.

Prof. Wing.—To obtain results we have to rely upon experimental data, and we have to use such formula as will best apply to those experiments. It makes but little difference what formula we use, so long as we do not use it outside the range of experiments. We must depend upon experiments for determining our coefficients of friction. Then we can adopt any formula that will apply to the range of experiments. Outside of this it is not safe to use any formula.

Mr. Henny.—I wish to correct a statement that has been made in regard to the Kutter formula. It is in no way based upon experiments made upon pipes. I do not know that Gauguillet and Kutter themselves advocate it for use on pipes, as none but experiments on open channels were used for a basis. Later, the formula was tested for pipe, and, so far as pipe with unobstructed interior is concerned, it was found to give better results than any other formula.

Mr. Hoskins questions the weight of the experiments made on semicircular open conduits, as applied to pipes. It seems to the author that the hydraulic differences between a half circle running full, and a full circle of the same diameter running full, are very small, much smaller than between deep and shallow open channel sections of various forms, to which the Kutter formula is conceded to apply, and that the experiments made by Mr. Darcy on semicircular conduits have a direct bearing on the full circular conduit, and are moreover in line with experiments on new cast iron pipe.

Considering the time and expense involved in making experiments of this character, it is not to be wondered at that individual engineers can so rarely follow their inclinations in this direction, and it is therefore all the more gratifying to learn that the experimenters on the Ogden pipe have made preparations to continue and extend the work commenced last year. The results will undoubtedly be awaited with the greatest interest.

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ADDRESSES DELIVERED AT THE MEETING TO COMMEMORATE THE SEMI-CENTENNIAL OF THE BOSTON SOCIETY OF CIVIL ENGINEERS, NOVEMBER 11, 1898.*

Opening Address by Howard A. Carson, President of the Society.

THE Boston Society of Civil Engineers is now over fifty years old, and we are met to-night to commemorate that fact in a simple and unpretending but I hope pleasant manner. In a short time Mr. FitzGerald will read us what I am confident will be an extremely interesting history of the Society. I think we can feel reasonably sure that our Society will continue to grow and prosper, and that fifty years from now there will be a meeting to celebrate its centenary. As many of our members are young, we may hope that some of those who are here to-night will be present at that celebration, and perhaps give an account of the somewhat quaint old Boston of 1898.

As human beings we are all interested in even the humble details of human life, and, as the effect of the work of engineers is to help feed, clothe, warm and transport the people, illuminate their houses and remove their wastes, we have a special interest in such details. With your permission, I will give a few scattered facts related to life in Boston fifty years ago.

The excellent collection of maps in the City Hall makes it easy to find the outlines of Boston at that day. Most of you are aware that Central Wharf, Long Wharf and other wharves extended up to India street and Commercial street and to the present

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Custom House. The Back Bay was then really a bay, and the water came up as far as the west side of the Public Garden, where Arlington street now is, and very nearly to Tremont street at its junction with Dover. The Worcester and Providence roads passed over a long expanse of water in this Back Bay, which was then called, on maps, the *Receiving Basin.* The extension of Beacon street west of the Public Garden was really a Mill Dam, and, as you know, that term has been popularly maintained to the present time. But two or three houses were found west of the Public Garden. The Boston and Maine Railroad, which a few months earlier ran its trains to the city over the Lowell road, was using its new station in Haymarket Square. The building was not nearly so large as that torn down on account of the subway during the last year. The station of 1848 extended no farther north than Market street, while the later one extended as far north as Travers street. The Lowell Railroad station was on Minot street, several hundred feet north of Causeway street. The Fitchburg road had just been extended from Charlestown, and entered the well-known granite structure on Causeway street, which it abandoned to enter the new Union Station four or five years ago. The Eastern Railroad did not enter Boston proper at all, but had its terminal station in East Boston, whence the passengers were ferried to the city. The local rates of fare on the railroads to stations a considerable distance from Boston were apparently about the same as now. You could go to Lowell in an hour. That is still the running time for a train stopping at most of the stations. You can go by an express in thirty-eight minutes. It may be of interest to note that the old Middlesex Canal to Lowell was still running its boats, although the opening of the Boston and Lowell and Nashua and Lowell roads had so reduced its receipts that they did not then cover the cost of repairs and current expenses. The boats continued to run until 1852. The Old Colony Railroad had a station on its present site, and the Boston and Worcester Railroad occupied a part of the station which still exists on Beach and Albany streets.

In September, 1849, there was a passenger train to New York which left Boston at 7 A.M., arrived at Springfield at 10.05, left there at 10.20 and arrived in New York at 4.10, all rail; and there was another train leaving Boston at 4 P.M. which arrived at New Haven at 11.05, connecting there with a boat by which you could arrive in New York the next morning. In 1850 it was possible to leave Boston at 2.30 P.M. and arrive at New York at 11.25 the same night. The price for a ticket to Worcester was then a dollar, the

same as now, and the road had a double track. Although passenger rates are not very different now from those of that day, freight rates, especially for a distance, are very much less. The average price per ton from Boston to Albany in 1848 was $2.80. At present it is about 95 cents. The road carries about sixteen times as much freight as it did then.

Every bridge leading from Boston at that time was a toll bridge. Roxbury, West Roxbury, Brighton, Dorchester and Charlestown were not then parts of Boston. The population of those places and of Boston proper, that is to say all that is included in the legal limits of Boston to-day, was about 174,000, the population to-day being about 526,000. If we take all within a radius of twelve miles, so as to include Lynn, the population at that time was about 290,000, and to-day about a million.

Boston had then had telegraphic communication with New York for two years, the office being in Court Square, where Young's Hotel now is.

Perhaps I may be allowed to mention that Parker, the famous restaurateur, who afterwards established the Parker House, had then a restaurant in a cellar under or near the telegraph office just mentioned. Dr. Green (ex-Mayor) tells me that he had table board there in 1848, paying therefor $3.50 per week. I presume many of our young engineering assistants, with large appetites and small salaries, would be glad if the present Parker House would board them at the rates that then prevailed.

The people of Boston of that day could buy their meat, butter and eggs for prices 25 per cent. less than they now pay, but we can buy to-day clothing and manufactured articles for perhaps 25 per cent. less than what they had to pay for the same article.

Boston had no electric cars, horse cars or bicycles at that date. It had, however, omnibuses running to Charlestown, Cambridge and the South End. The fare to Cambridge was 15 cents. I need hardly say that the telephone did not then exist, and there are hundreds of other less important inventions which had not then been brought into use, such, for example, as the steam fire engine.

In 1848 the Cochituate Water Works had just been completed, and Chesbrough and other engineers employed thereon were later to have a wide reputation.

The illumination of houses at night at that time was mainly by sperm oil and lard oil lamps, but the Boston Gas Light Company was in existence and had about 2000 customers. It has about nineteen times as many now in the same territory. The price was $3.50 per thousand cubic feet then, as against a dollar now.

The steamers of the Cunard Line, the "America," "Niagara," "Canada" and "Europa," were placed on the line between Boston and Liverpool in 1848. Each was a fifteen-day boat a little over 200 feet long, of 1200 to 1500 tonnage and of about eight knots speed. Their latest successors in the passenger business from New York are five and one-half-day boats 620 feet long, and of 13,000 tonnage. Within a year the "Oceanic," of 20,000 tons, 704 feet long, with engines of 44,000 horse power and estimated speed of twenty-seven knots, is expected to lower the colors of the present champions.

It is thought that the following table shows approximately the relative proportions, now and then, of the profitable and non-profitable portions of the loads of trans-Atlantic freight vessels fully laden:

Percentages of weight of displacement on steam freight vessels for a voyage between Boston and Liverpool.

	Hull.	Machinery.	Coal.	Cargo.
1848	45% to 50%	10% to 12%	30% to 40%	10% to 15%
1898	25% to 40%	5% to 10%	4% to 10%	40% to 60%

N. B.—The foregoing figures are not based on equality of displacement or of speed.

If the foregoing table is correct, it appears that there was then required for the voyage between Boston and Liverpool two tons or more of coal for each ton of freight, while to-day one ton of freight can be carried the same voyage with one-eighth of a ton or less.

Among the elements on which this marvelous development is based may be mentioned the substitution of steel for wood and iron in hulls, giving 50 per cent. increase of strength for the same weight; that of compressed and cast steel for cast and wrought iron in machinery, giving still greater advantages; the increase of boiler pressures from 10 to 300 pounds as reported; the increase of engine speed from 50 to 400 revolutions per minute; the multiple cylinder; the surface condenser.

The greatest improvement of all in our material condition is perhaps to be found in what is called the sanitary condition of our cities and our houses. As far as comfort and cleanliness are concerned, we are very much better off than were the people of Boston of 1848.

We may exercise our imaginations in thinking of what will be the condition of Boston when our Society has its centennial celebration fifty years hence. That methods of transportation will have been modified and quickened seems very probable. I will

not hazard a conjecture that flying machines or air ships will be in extensive use. Buildings are much more brightly illuminated now than they were fifty years ago, and the intensity of illumination will probably continue to increase. It is a notable effect of most inventions in the material world that they tend to diffuse comforts and luxuries among impecunious grades of society, and we can safely, I think, predict that this will continue to be the tendency in the future. The daughter of a comparatively humble citizen has a piano to-day. The daughters of day laborers may have them before 1948.

In considering the question of advance in material comfort of the man of 1898 over that of his predecessor of fifty years ago, the question arises, Is the moral condition of the citizen now better than it was then? In 1848 the Mexican War had recently been terminated, but the Napoleonic wars had then been finished for about as long an interval as that since our Civil War. Some writers then believed that the time had nearly or quite arrived when war would cease. During the next generation, however, wars were to follow which, measured by fierceness, loss of life and property and number of men engaged, were as terrible as any known in history. According to geologists, man has lived on the earth for several hundred thousand years, and it is believed that he has been fighting most of that time. The writers of fifty years ago went too far when they supposed that man's savage nature could be so quickly and easily changed. Those who have read the editorials, speeches and sermons of the last few months will conclude that the people of to-day are at least as sanguinary as they were two generations ago.

There is this, however, to be hoped for in the future. If we look back over very long periods it appears that man is not only improving in his environment of physical comforts, but that his nature slowly grows less savage. It seems reasonable to suppose that, as the good things of life become diffused to a greater extent than at present, the people of the future may be somewhat gentler in mood and action than those of to-day, just as well-nourished people around a plentifully spread table politely regard each other's rights and comforts, as compared with emaciated hungry men scrambling for scanty food.

I have now spent as much time in talking about the Boston of fifty years ago and conjecturing about the Boston of the future as should be so devoted by me this evening, and I take great pleasure in calling upon Mr. FitzGerald for the history which you are eagerly awaiting.

Historical Address by Desmond FitzGerald, Past-President of the Society.

FIFTY years have now passed since a small band of engineers met in Boston for the purpose of organizing a Society of Civil Engineers, and to-night we are gathered to celebrate the semi-centennial of that Society.

Fifty years ago, not only the Boston Society of Civil Engineers, but the profession of engineering itself, was struggling to gain a footing in this country. To-day the child has grown to be a man. To-day we not only realize that the profession stands on a strong and vigorous foundation, but we also know that the present eventful period, rich with the light of progress, opens to the profession opportunities for usefulness and advancement which could hardly have been dreamed of when the foundation stones were laid.

Our corporate existence to-day, although a respectable one, is yet but the first flush of strong and vigorous manhood, which looks back upon the days of youth with interest not unmixed with wonder, and turns to the future as to a beneficent harbinger of prosperity.

On April 26, 1848, an informal meeting was held at the United States Hotel in Boston to consider the expediency of taking measures to form a society for social intercourse and professional improvement, to be composed of civil engineers and of gentlemen engaged in pursuits kindred to civil engineering. Of about twelve persons invited there were present: John H. Blake, E. S. Chesbrough, George M. Dexter, Henry S. McKean, William S. Whitwell.

Of these five engineers two only remained in practice to the ends of their lives; one of these worked his way to the very front rank, and the other ended his own life in disappointment and despair. The remaining three followed pursuits other than engineering.

This was the first meeting of engineers in the country gathered for the purpose of forming a society from which any tangible results followed. If it could be considered as the first meeting of the Boston Society of Civil Engineers, then the birth of the French Society, which, by a happy coincidence, was founded on March 4, 1848, preceded our own by only a little over a month and a half. This is, of course, enough to give the French Society all the honor that may go to the first-born. The Boston Society of Civil Engineers was not formally organized, however, until June 15. The first meeting was held on July 3, which date has been, I

think erroneously, accepted as the date of organization. If June 15 be adopted as the date of organization, then our sister French Society is our elder by three months and eleven days, and to this extent at least we must acknowledge her superiority.

The foremost association of engineers in the world, the Institution of Civil Engineers of England, received its charter of incorporation June 3, 1828, although meetings were held prior to that time as far back as 1817. Telford was the first President. The property of the institution is now valued at $500,000, and the ordinary income of the Society is $125,000.

Whatever our standing may be in point of age when compared with foreign societies, our glory at home is unquestioned. The American Society of Civil Engineers was instituted November 5, 1852, and is, consequently, four years and five months our junior. The Engineers' Club of Philadelphia dates from December, 1877.

From 1848 to the present time, the light of the Boston Society has burned continuously and brightly, with the exception of that little gap from 1861 to 1874, when the oil was being replenished.

The following is a list of the early members of the Society, 1848-1861: Samuel Ashburner, Waldo Higginson, James F. Baldwin, Isaac Hinckley, Joseph Bennett, Josiah Hunt, John H. Blake, Martin B. Inches, Simeon Borden, Samuel F. Johnson, Uriah A. Boyden, James Laurie, E. S. Chesbrough, Henry S. McKean, John Childe, Samuel Nott, Marshall Conant, George A. Parker, Franklin Darracott, William P. Parrott, William L. Dearborn, T. Willis Pratt, George M. Dexter, Theophilus E. Sickles, Sereno D. Eaton, Lucien Tilton, Robert H. Eddy, William S. Whitwell, Samuel M. Felton, Thomas S. Williams, James B. Francis.

The following were Presidents of the Society, 1848-1861: James F. Baldwin, George M. Dexter, Simeon Borden.

Obituary notices have never been prepared of either of the early Presidents of the Society. It is a token of love which should be undertaken, and that before it becomes too late.

The first officers of the Society were: President, James F. Baldwin; Vice-President, George M. Dexter; Secretary, John H. Blake; Treasurer, William P. Parrott; Directors, Samuel Ashburner, Joseph Bennett, James Laurie, Samuel Nott, William S. Whitwell.

The most frequent attendants at the early meetings were: Messrs. Ashburner, Bennett, Chesbrough, Dexter, Nott, Parrott and Whitwell.

Among the early members may be particularly mentioned Samuel Ashburner, Samuel M. Felton, James F. Baldwin, James B. Francis, Simeon Borden, James Laurie, Uriah A. Boyden, Samuel Nott, E. S. Chesbrough, Theophilus E. Sickles, distinguished engineers, who left their mark in the profession.

James F. Baldwin was one of a large and celebrated family of engineers, of whom Loammi was considered by some to be the father of his profession in the United States. James was a railroad engineer. He built the Boston and Lowell Railroad, wrote a treatise on railroad curves, and was one of the commissioners to introduce the Cochituate water into Boston.

Borden established what have always been known as the Borden points in the trigonometrical survey of the State. Boyden brought the turbine to the highest degree of perfection. Chesbrough shared with Francis the highest pinnacles of fame in the profession; the former's work was particularly identified with the water systems of Boston and Chicago, and the latter was known all over the world as a leader in hydraulic science and its application in the magnificent water development at Lowell. Felton became a distinguished manager of railroad properties.

James Laurie was a well-known railroad engineer, and was at one time chief engineer of the New Haven, Hartford and Springfield Railroad. While engaged on this railroad he designed and built the bridge across the Connecticut River at Warehouse Point. This bridge, for that period, was one of the most remarkable in the country. It was a riveted iron bridge built in England. One of its spans was 177.25 feet long. The cost of the bridge, erected and completed, was 12.38 cents in gold per pound.

Mr. T. E. Sickles was at one time chief engineer and general superintendent of the Union Pacific Railroad. In 1874 he was designated by the President, General Grant, as one of a commission of seven engineers to recommend to Congress the proper method for securing an open mouth to the Mississippi River. In 1876 he was one of the judges of the Centennial Exposition in Philadelphia, and in 1878 was a representative of the American Society of Civil Engineers at the Paris Exposition. He was a man of remarkable originality and of independent judgment.

This is a brilliant array of talent for the early founders of any learned society, and one of which we may justly be proud. The pioneers of the profession were men of industry, which is better than genius; of sterling integrity, which is better than brilliancy; of determination, which is sure to bring success. They were self-made men, whose whole lives were given to study; who denied

themselves pleasure and recreation to make up by close application for deficiencies in training. Who can recount their early struggles against poverty and their steadfast devotion to the highest aims? Their characters, their works and their attainments are their best epitaphs. Many of them lived to see that enlargement of the professional field and the dawn of that wonderful prosperity which have characterized the last generation.

It is interesting to glance at some of the topics of discussion at the early meetings in 1848. We have "The Coal and Iron Trade of Great Britain and the United States," by James Laurie; "The Carrying of Water Pipes to South Boston," by W. S. Whitwell, and by the same author a description of the Beacon Hill reservoir, a reservoir which was expected to last for centuries, but which was removed a few years ago as having outlived its usefulness; Mr. Chesbrough, on contracts; Mr. Blake, on the use of lead pipes for carrying water; the failure of the dam at Hadley Falls, by Messrs. Nott and Parrott.

On September 3, 1849, Mr. Kyan, of London, appeared before the Society and gave an account of the kyanizing process for the protection of timber.

On September 11, 1849, occurred the death of Major George W. Whistler, one of the most distinguished members of the profession in the United States, and probably at that time the civil engineer of widest fame. Major Whistler was selected by the Czar of Russia to build the railroad from St. Petersburg to Moscow, and for this he was decorated with the Order of St. Anne. A committee of five was appointed to attend the funeral at Stonington.

On December 3, 1849, the feasibility of the project of building a railroad to the Pacific was discussed.

The explosion of locomotive boilers seems to have been a rather frequent occurrence in those early days, and the Society was often called upon to investigate the causes of these explosions.

In 1850 appeared Mr. Bennett's translation of D'Aubuisson's "Hydraulics," a standard treatise, which, at that time, was supposed to represent the accumulated knowledge of the world on that subject. The translation into English by one of its own members was a work in which the Society felt a proper pride. The translation was dedicated to the Boston Society of Civil Engineers.

The early transactions of the Society have been neatly copied into a quarto MS. volume, which is preserved in the library.

On April 24, 1851, an act to incorporate the Boston Society of Civil Engineers was obtained from the Legislature, and the

names of George M. Dexter, Simeon Borden and William P. Parrott appear as incorporators. It is under this act, authorizing us to hold real and personal estate, not exceeding in amount $20,000, that we now exist.

On February 9, 1852, the act was accepted by the Society. The membership at that time was twenty-seven, and the average attendance at the meetings about twelve.

Previous to June 3, 1853, the Society had its room at No. 114 Joy's Building, but after this it met at the room of the Association of Railroad Superintendents, No. 11½ Tremont Row, where, by mutual agreement, the two Societies used the rooms and the library in common.

The Society continued in a prosperous condition, holding regular meetings, which were generally well attended, until the spring of 1855. After this time but very few meetings were attended by a quorum, and consequently no business could be transacted.

In 1860, the lurid cloud of the War of the Rebellion appeared upon the horizon, and when the storm burst the excitement and trouble swept the existence of the Society before it. The modest assets were sold, all debts extinguished and the balance, $1.53, given to the Boston Athenæum, where the records and about one hundred other books were deposited for safe keeping.

The property of the Society reposed peacefully on the shelves of the Athenæum while the waves of war beat upon the land, and when at last the sunshine of peace was fairly established they were resurrected to form a foundation for the second period of existence of this Society.

To this period we will now turn.

On May 30, 1873, a number of engineers in Boston and vicinity organized as "The Boston Society of Civil Engineers," and held meetings, mostly at the Massachusetts Institute of Technology. It was soon brought to the notice of this body that they had unwittingly taken the name of a society which in fact existed, although in a state of desuetude. Proper legal steps were at once taken to revive the real Boston Society of Civil Engineers, with its Legislative charter. Three of the original members—Messrs. Darracott, Pratt and Higginson—petitioned a justice of the peace to issue an order requiring Franklin Darracott, in the name of the Commonwealth, to call a meeting at the office of Mr. Ernest W. Bowditch, at 60 Devonshire street, on the 27th day of April, for the purpose of choosing officers, and directing notices to be sent to all the known members of the original Society. It was found

that there were eighteen living members, and they were all duly notified.

Pursuant to this warrant, a legal meeting was held as above, at which five members were present,—viz, Messrs. Francis, Darracott, Higginson, Nott and Pratt. Mr. James B. Francis was elected President and Mr. Samuel Nott Secretary.

Eighty-eight new members were elected, these members being those already included in the list of members of the Society formed May 30, 1873.

On June 8, 1874, the officers of the newly reorganized Society tendered their resignations, and on August 7 Mr. Thomas Doane was elected President and Mr. George S. Rice Secretary.

At the meeting on September 4, 1874, the organization was completed by the election of other officers, and in October a constitution and by-laws were adopted, and the old Boston Society of Civil Engineers was fairly launched on its second period of existence.

It is worthy of notice that the first paper read before the reorganized Society was on the Metric System.

In 1874, when the Society was reorganized, the first meetings were held at the Massachusetts Institute of Technology, which has always generously opened its doors to the Society whenever the latter has found itself homeless. In 1875 and during the early part of 1876 a room was obtained at 66 State street and fitted up for the Society. Meetings were held here until May 17, 1876, when a move was made to the small committee room in the rear of Wesleyan Hall, 36 Bromfield street. In these cramped quarters the Society remained for nine years. It seems almost incredible that the Society could have been content with these premises for so long a time; and yet, during these years, many important meetings were held and many interesting professional questions discussed. On October 21, 1885, another move was made, this time to the station of the Boston and Albany Railroad, where a room on the upper floor was kindly furnished by the railroad company, free of charge, for the common use of this Society and the New England Railroad Club. The Society remained at the Boston and Albany Station for four years.

It was at this time that the members formed the habit of dining together on the evenings of the meetings, a custom which has been happily preserved to the present time, and which it is hoped will never be given up.

It was in the room at the Boston and Albany Station that the library for the first time became really accessible.

In 1889 the railroad company wished to make use of its room, and in September the Society was obliged to withdraw to the Institute of Technology.

After trying several places, a room was finally obtained at the American House, on Hanover street, where the meetings were held for more than two years. The library was placed in a small room near the larger room in which the meetings were held. The principal advantage of the American House location was the opportunity afforded for dining on special occasions in a large hall at a moderate price. It is easy to recall many delightful meetings held at the American House and attended by some whose faces will, alas, never be seen with us again.

In June, 1892, the Society again moved its quarters to Wesleyan Hall, but this time to the large hall, for which favorable terms were secured. A room near the hall was obtained for the library, and here many informal meetings were held for the discussion of passing events of engineering interest. A table in the center of the room was well covered with current professional literature. It was not long before the shelf room was outgrown, and it became evident that, to gain the full advantage of our growing library, larger quarters must be secured.

During the autumn of 1894, efforts in this direction were begun, and in October, 1895, an agreement was reached with the trustees for the new Tremont Temple building for the use of a portion of the seventh floor. In March, 1896, a lease was executed for three years, with the privilege of renewal for three years more. The rooms, together, measured 18 by 43 feet, and a mutually advantageous arrangement was made by which the New England Water Works Association and the Hersey Manufacturing Company were to share the use of the rooms. On the floor below the library was Chipman Hall, a convenient and spacious hall for the meetings of the Society.

On May 20, 1896, the semi-centennial anniversary of him who is now addressing you, who will long have occasion to remember it with pleasure and gratitude, the Society moved into the Tremont Temple. When compared with anything enjoyed heretofore, the new quarters of the Society seemed indeed palatial. The shelf room appeared ample for a number of years. The furniture and appointments of the library were all in the best of taste. The bookcases, however, have filled rapidly, and they already give warning that even these delightful quarters will soon become severely taxed.

We have now become so accustomed to having a Committee

on Quarters that a permanent committee has become grafted onto our list of officers, and seems as necessary for our welfare as any other of the permanent committees of the Society.

A commodious and well-appointed club house, fitted to the growing needs of the profession, has been the dream of the members for several years.

I believe it has been generally felt that all of our many abiding places, covering a long pilgrimage since 1874, not unlike that of the Children of Israel, are simply temporary homes, endured patiently for the time being, while the Society gains in growth and slowly but steadily advances in material prosperity.

It is a gratifying fact that so far no false step has been made, and all of our financial transactions have been marked by a wise conservatism.

In 1878 the permanent fund amounted to $1,000, invested in a five per cent. United States bond. In 1889 the treasury contained $3,095.86, and in 1898 the permanent fund has accumulated to $8,423.01. The current expenses of the Society are about four thousand dollars yearly.

Some idea of the early resources of the Society, after its reorganization, may be formed when it is considered that in April, 1877, the Secretary was directed "to ascertain the cost of printing a list of members and report." The number of members at this time was seventy-two. The average attendance was eighteen. In 1888 there were two hundred and fifteen active and four honorary members. The average attendance of members and visitors was seventy, the maximum one hundred and fourteen and the minimum forty-eight. In 1898 the number of members has risen to four hundred and fifty-five, with five honorary and five associate members, and the average attendance is about ninety-five.

In March, 1879, the sum of $200 was appropriated to print the papers and proceedings, and, as a result, appeared the first printed records from September 17, 1879, to June, 1881, both inclusive, forming a volume of one hundred and forty-four pages.

On January 19, 1881, an important step was taken when it was voted to join the Association of Engineering Societies, an Association formed for the purpose of a joint publication of the papers and proceedings of the Societies forming it.

From June, 1881, to the present time, the papers and transactions of the Boston Society have appeared in the printed journal of the Association.

The present prosperity of the Association of Engineering Societies is largely due to the intelligent and persistent efforts of

our honored Secretary, Mr. S. E. Tinkham, who was a member of the Board of Managers at its organization and for several years its chairman, and to Mr. John C. Trautwine, Jr., Secretary, who has held that office for the past four years. Under this management the mailing list of this Association has risen to twelve hundred and fifty-two.

The growth of our library has been a gauge of our increasing strength. In 1878 the number of books was merely a handful. In 1888 the bound volumes amounted to five hundred and ten. In 1898 the library has risen to the dignity of thirty-two hundred and twenty-six. To the disinterested efforts of Messrs. Clarke, Brooks, Kettell, Noyes, Woods, Hodgdon, Bryant, Locke, Flinn, Fuller and Fales the members are greatly indebted for the present dimensions of our library and for the convenience of its arrangement.

For a number of years past we have been in the habit of enjoying together an annual dinner, and this feature, together with the monthly excursions, have, in a measure, become settled institutions. The first annual dinner was in March, 1883. Until 1890 the annual meetings and dinners were held together, but after an experience of seven years it was thought best to make the dinner a separate feature held on a different day, and this custom has prevailed to the present time. Our last dinner, in March of this year, was the sixteenth in succession. There were present at the tables one hundred and sixty-one members and guests. It is needless to say that many good things besides the viands are passed around on these occasions. This happy institution will receive a serious blow when Mr. Henry Manley ceases to take an interest in the preparations for this event.

The plan of making excursions to various points of engineering interest in the vicinity of Boston was begun in 1885, and in 1886 the government was authorized to appoint a Committee on Excursions. This feature has proved successful, although the wonder grows where the able Committee on Excursions continues to find new fields for explorations. Perhaps it is one of the duties of the profession to build new works fast enough to keep up the supply.

If I had been mentioning the officers of the Society in the order of importance, I should have put the Secretary first. It needs no feeble words of mind to gild the work which our present popular and devoted Secretary has so faithfully performed for this Society for so many years. Long may he be spared to sign the calls for our meetings, and long may he hold the idea, even if he

does not already hold it, that the office is his by right of propriety and possession. Mr. Tinkham was first elected Secretary in April, 1880, and he has held the office ever since, with the exception of the period from 1882 to 1887, when Mr. Horace L. Eaton was Secretary.

Long as Mr. Tinkham's term has been, it was exceeded by that of Mr. Samuel Nott, second Secretary of the Society, who held office from March 6, 1849, to August 7, 1874. The Society is fortunate in having Mr. Nott present to-night. He is the only one of the founders who is able to attend our semi-centennial. The work which he performed for the Society so many years ago is fully appreciated by the present members, who have reaped the benefits.

Honored sir,—you have come down to us from the very foundation of the Society. You alone of your contemporaries have been spared by divine providence to witness here to-day the development of that seed planted in 1848, from a handful of professional brothers to the strong and vigorous Society that you see here to-night. You never could have foreseen that the passage of fifty years would change to such a degree the status of the profession to which your long life has been devoted, and it will be ever a consolation to your declining years to know that to you and to others of your co-laborers was given the honor of founding the Boston Society of Civil Engineers, the first organization of engineers in America.

For our part, we desire to extend to you our hearty congratulations, and to wish you that well-earned happiness which is the accompaniment of a long life spent in the service of your fellow-man.

After Mr. Nott's retirement, Mr. George S. Rice held the position for six years and most acceptably to the Society.

The early Presidents have already been alluded to. Since 1874 the Society has had fifteen Presidents, as follows: Messrs. Francis, Doane, Davis, Vose, L. F. Rice, FitzGerald, Herschel, Stearns, Manley, Freeman, McClintock, Noyes, Swain, Brackett and Carson, an honored list, in whose company any one may well be proud to be enrolled.

I come now to our deceased members,—a list which is naturally scanned with a sad heart, it contains so many whose faces have been familiar at our meetings and whose presence was an inspiration to our own lives. There are fifty-six names on this list. I have taken upon myself the privilege of preparing brief biographies of these deceased members, for convenience of refer-

ence, forming an appendix to this address,—a few words only for each, but sufficient as an index to the principal life work of each one.* There are three names, however, upon which I must here linger for a moment, as they represent three Past-Presidents of the Society since its reorganization, who have passed to their long reward.

The life and work of James B. Francis are already well known, and I will not attempt to reiterate what has already been so fully portrayed. Mr. Francis was the first President under the reorganization and for a very brief period. His home was so far from Boston that he could not conveniently take part in our proceedings, but his counsel and advice were frequently sought, and never in vain. We all hold his memory precious. He was a true type of the civil engineer,—of sturdy integrity, possessed of brilliant abilities combined with soundest common sense. He climbed the ladder of fame with a sure and steady footstep. His great work in the development of the water power of the Merrimac River at Lowell will always remain as a remarkable achievement in the history of hydraulic engineering on this continent.

"Let us weep in our darkness, but weep not for him;
* * * * * * * *
Not for him who has died full of honor and years;
Not for him who ascended Fame's ladder so high;
From the round at the top he has stepped to the sky."

Thomas Doane was President of this Society for nine years,—1874 to 1884,—and was for twenty years an active member of the Society. He probably took as deep an interest in the welfare of everything connected with this organization as any member inscribed upon its rolls. It seems but yesterday that he was here to aid in our counsel and to add some item of engineering interest to our meetings. Mr. Doane was best known as a railroad engineer, and at one time or another, I believe, he was connected with almost every railroad leading out of Boston. He was Chief Engineer of the Burlington and Missouri River Railroad. Much of his interest was centered in the development of Nebraska, and he was the founder of Doane College in that State. Many a day will elapse before the Society finds a truer friend than Thomas Doane.

Mr. Albert F. Noyes, who was President in 1895, passed away in the prime of life. and so recently that we can hardly realize that he has gone on that long and mysterious journey from which there is no return. Mr. Noyes was long and prominently connected with the advance of this Society, and he filled many of its offices

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*Omitted.

before he was called to preside at our meetings. If Mr. Noyes had been more sparing of his own strength and more considerate of his own comfort, he would probably be with us to-night to share our pride in this delightful celebration of an event in the history of a Society which he loved so well and for which he labored so faithfully.

Mr. Noyes was City Engineer of Newton for sixteen years, from 1877 to 1893, and brought that office to a high degree of efficiency. He was afterwards connected with the work of the State Board of Health, and in 1895 was appointed on the Metropolitan Sewerage Commission, where the Commonwealth received the benefit of his ability and experience.

Time will not permit me to name other honored members of the Society, who, in one office or another, have contributed to its welfare. The men whom we meet here night after night and year after year are men of sterling worth whom to know is to respect, and who can be trusted in all the emergencies of life. It is gratifying to know that the public is taking the same view, and that in one place or another important positions are thrust upon our members outside of their regular professional duties. As I scan the list, I find many who hold positions on State, municipal or town commissions, where their influence is always felt on the right side of public questions. A friend remarked to me facetiously, not long ago: "You engineers are fast absorbing to yourselves all the best places in life." I could not help smiling at the thought, especially as my friend happened to be a member of the bar.

Among the passing tokens of regard with which the public are beginning to appreciate the work of the profession, it is worthy of notice that the only name which appears upon the portal of that recent triumph of engineering skill, the Boston Subway, is that of our worthy President, Howard A. Carson, a graceful tribute by the commissioners to his ability and achievements.

In what has already been said, I have attempted to give an historical account of the formation and progress of this Society during the past fifty years. Such a narrative must necessarily deal with facts which can be of little interest outside of our own membership, and with statistics which, I am afraid, tax even your patience. I trust, however, they may at least be useful in bringing to your minds the paths, more or less familiar, which we together have been following at different times in this eventful half-century, —paths at times clouded by the passing storm, and perhaps even at times by failure, but more often illumined with the bright rays of success and of progress.

In the laborious and responsible work of the profession there is little time for looking backward; the swimmer who turns his eyes from the goal is cast into the eddy; but there are times when retrospection is profitable, and a glance into the past, at least once or twice in a century, is instructive and at least pardonable.

As we consider the record of this Society, founded by the early toil and constant struggles of the fathers of the profession, built solidly on the eternal principles of truth and honesty, and rising slowly but surely out of every discouragement to its present commanding proportions, we have reason to be proud,—proud of our Society, and proud of the achievements of our members in every branch or specialty of the work of the civil engineer, who, by patience, by industry, by ability, and, best of all, by unswerving integrity, have aided in lifting the noble profession of engineering to its place among the great professions of the world.

THE NATURE AND HISTORY OF PATENT RIGHTS.

By E. L. Thurston, Esq., Associate Member of the Civil Engineers' Club of Cleveland.

[Read before the Club, December 13, 1898.*]

The patent rights to which this paper relates are those rights respecting an invention which are created by the grant of a patent for that invention.

Until a patent is granted for it an inventor has no property rights whatever in his invention as such. It is true he may own the particular machine or instrument in which his invention is embodied, but he has no ownership in the invention itself until the patent is actually granted and issued. In the meantime others may make, use and sell similar machines or instruments containing the invention without infringing upon any of the inventor's rights. Under the common law every person has the right to make anything he wishes to make out of materials which he owns, and it is equally his right to sell the thing so made or to use it when and where he chooses, provided such use is not harmful to the public. It is only by the grant of a patent, authorized by the statute laws passed by Congress, that an inventor acquires any special rights or privileges respecting his invention.

The right created and secured by a patent is, to quote from the granting clause of a patent, "the exclusive right to make, use and vend the invention throughout the United States and the territories thereof" for seventeen years. The language quoted is ambiguous and deceptive, and is responsible for a widespread misapprehension as to the nature of the rights secured by the patent. Many persons believe that a patentee has, by virtue of his patent, the absolute right to make, use and sell his invention; but that is not the fact. The patent secures to him the "exclusive right to make, use and sell his invention," but to understand just what this right is you must put the accent on the word "exclusive." A patent secures to the patentee the *exclusive* right to make, use and sell his invention. The patent is a grant of exclusion, and that only. It secures to the patentee the right to exclude or prevent others from exercising their natural right to make, out of their own materials, the particular article the invention of which the patent covers; and that is the only right respecting an invention which is created by a patent. It does not give or purport to give to the inventor absolute right to make, use or sell his invention.

*Manuscript received December 31, 1898.—Secretary, Ass'n of Eng. Socs.

If he had that right before his patent was granted he has that right after the grant, but otherwise he has not.

As I previously stated, it is the natural right of every person to make what he wishes out of his own material, but each patent which is granted to another restricts that right. It removes for seventeen years the particular invention which it covers from the group of things which the public may use and sell. There are now in force more than 360,000 patents, each of which acts to thus restrict the natural right of every person except its owner; because, as before stated, the owner of every patent has the right to prevent you and me and everybody else from making, or using or selling the invention which his patent covers. Clearly, the grant of a patent to one of us can not take away the right previously granted to another; and in many cases it would do that if it granted to the patentee the absolute right to make and use his own invention. Most inventions are improvements upon, or changes in, or modifications of, or additions to, old things. The first inventor of every improvement has the right to a patent by which he can prevent others from using it, but he may not be able to make use of it himself because some previous patent may have secured to its owner the right to prevent others from using some part of the thing improved, without which the improvement is useless.

A familiar example of this condition of things existed for many years with respect to the telephone which was invented by Bell, who was granted a broad patent for his invention. Before this Bell patent expired more than five hundred patents for improvements on the telephone were granted. These improvements were of all kinds, good, bad and indifferent; but, whether good or bad, the patentees could not use their own patented inventions, because in so doing they would necessarily use Bell's invention and thereby infringe Bell's patent; or, in other words, they would do that which Bell, by virtue of his patent, had the right to exclude them from doing. Under conditions like these there is a sort of deadlock. The owner of the original patent cannot use the improvement without the permission of the owner of the improvement patent, and the latter cannot use his improvement without the permission of the former. Ordinarily, if the improvement is valuable, the two get together upon some equitable basis.

Although, as I have stated, property rights in an invention, as such, do not exist under the common law, and may be secured only by the granting of a patent, inventors in this country are not dependent for the grant upon the caprice of any one. Congress has enacted patent laws by virtue of which the first inventor of any

new and useful art, machine, manufacture or composition of matter has the positive right to the grant of a patent upon complying with certain prescribed conditions. Congress derives its authority to pass patent laws from the Federal Constitution, wherein it is set forth that "Congress shall have power to promote the progress of science and the useful arts by securing to authors and inventors for a limited time the exclusive right to their respective writings and discoveries."

The wise framers of our Constitution recognized these facts, which our history as a nation has abundantly substantiated,—viz, first, that progress in the useful arts would be promoted by stimulating invention; second, that invention could be stimulated by offering a reward to inventors, and, third, that the fairest method effecting that result would be to make the reward as nearly as possible commensurate with the value of the invention to the public. In theory, at least, no better method could be devised than that which gives to the inventor, for a limited time, the control of his invention. He may, within that time, make out of his invention such profit as the public demand for it or its product will yield. If the invention be valuable to the public the inventor's profits will be correspondingly large. If the invention be of little importance the inventor's profits will be proportionately small.

The legal machinery for enforcing the patent laws, to the end that the inventor may obtain his promised reward, is not perfect. Like other machinery, it sometimes works better in theory than in practice. I believe, however, that the rights of a patentee may be enforced as speedily and as effectively as can any other right which must be enforced by law.

There are two theories as to the nature of a patent right. Under one theory it is a monopoly. Under the other theory it is a contract between the inventor and the Government representing the public.

The contract theory is fortunately that which has been generally accepted by the courts and by Congress in this country. Under the contract theory the Government may be said to have a standing offer to inventors in substantially this form: The Government will grant to every inventor for seventeen years the exclusive control of his invention, provided it be new and useful, and provided he will, in the manner and form prescribed, make a full and complete disclosure of the invention to the public, so that the public may understand how to make and use it after the term of the grant has expired.

An inventor is under no obligations to accept this proposition.

He may lock the invention in his own mind, where it was born. He may practice it in secret if he chooses to, and if the nature of the invention will permit it. If he does accept the proposition the public gains the complete knowledge of the invention, and, in compensation for this knowledge disclosed by the inventor, he acquires the exclusive right to control the invention for seventeen years.

This exclusive privilege does not take from the public any right which it had before enjoyed, because it is one of the essential prerequisites of a valid patent that the invention must be new. The only hardship which the grant imposes upon the public is that it must for a time either do without that which it never had or that it must obtain the right to use the invention, if at all, upon the inventor's own terms.

In the eyes of the law it is not unimportant to determine definitely whether a patent is a monopoly or a contract. It is not a mere question of words. If a patent is a monopoly it is a grant in derogation of common right, and as such it should be construed strictly against the patentee and in favor of the public. The language of the patent should be carefully and critically examined, and whatever is not positively and unequivocally included in the grant, whether invented by the patentee or not, should be held to belong to the public.

If, on the other hand, the patent is a contract it should be construed, as all contracts should be, liberally and fairly, and as nearly as possible in accordance with the intention of the parties as expressed by the patent. It is always the intention of an inventor to secure complete protection for his entire invention. It is the promise of the Government that he shall receive complete protection for that invention which the patent covers. Under the contract theory the patent should not be subjected to over-nice criticism. If the language employed by the patentee in his claims will permit such construction, it should be construed so as to afford complete protection not only for the particular embodiment of the invention shown and described, but for its mechanical equivalents. This, fortunately, has been and is the attitude of our courts upon this subject. It sometimes happens, however, that the claims of patents are so unskillfully formulated that their language cannot be construed to protect the invention. Under the contract theory the patent is the contract instrument. The specification and drawings constitute that part of the instrument which discloses the invention, and it is the consideration passing from the inventor to the public. The grant, found on the first page of a patent, is the consideration passing to the inventor from the public, and the

claims define the subject of the grant. The claims are brief statements made by the inventor, or his attorney, which point out which part or parts of the entire thing described the inventor claims to have invented. It is left to the inventor to make his own definition of the boundary of his grant. If he claims too much the Patent Office will refuse the patent. If he claims too little the patent is granted only for what he claims, and he loses part of the protection which he might obtain. It is therefore very essential that the claims of a patent shall be skillfully drawn, because the courts, while they will liberally construe the claims which are in a patent, will not make new claims and will not construe the claims to mean something which their language plainly does not mean. Many a valuable invention has been sacrificed by unskillfully drawn claims.

Let us now consider briefly the other theory of the patent privilege,—viz, that it is a monopoly. The patent right is undoubtedly a monopoly in a limited sense. But it is not an illegal monopoly, as defined by Blackstone and all of the later legal writers. Blackstone defines a monopoly as "a license or privilege allowed by the King for the buying, selling, making, working or using of anything whatsoever whereby the subject in general is restrained from that liberty of manufacturing and trading *which he had before*." A patent right is not a monopoly in that sense. It does not, as a matter of fact, deprive any individual of any right he had before, because, as before stated, it is one of the essential prerequisites of a valid patent that the patented invention must be new. It must never have been known to or used by others before the inventor originated it. And no individual can be said to have been in actual possession of a right when neither he nor any one knew how to exercise that right. The patent right is monopolistic in form only, but so also is every property right. A man who owns a horse or a house, or any other thing, has, by virtue of that ownership, the exclusive right to use that thing.

The theory that the patent privilege is a monopoly had its origin in the fact that the early history of the British patent system, of which our patent system is the direct descendant, is inseparably connected with the history of those illegal monopolistic grants by the English kings, against which the famous Statute of Monopolies was aimed.

Briefly, the early history of the birth and growth of the British patent system is the following: In the early history of trade and manufacture in Europe capital was timid. It needed encouragement and protection. The people in those days were not strict

observers of the rights of property. Might made right. The beginning and carrying on of trade and business was hazardous. Communication between different cities and countries was difficult and dangerous; and the assurance of large profits upon successful ventures, to balance losses upon unsuccessful ventures, was necessary to tempt capital into trade, and especially to induce merchants to engage in foreign trade, which would bring into the country new manufactures; that is to say, new manufactured things and the knowledge of the art of making them. To encourage capitalists to enter trade and manufacture the English kings at an early day began to exercise their royal prerogative by granting special privileges to such persons. The promotion and development of towns as centers of domestic trade and manufactures were also encouraged by royal grants of political immunities or commercial franchises.

Practically all of the early royal grants of special monopolistic privileges had been made directly to merchants, or to manufacturing or trading companies, as inducements to enter business, or as rewards for having done so. But later the crown began to grant monopolies for money paid or for services rendered the crown. Monopolies were sold by the crown to persons who sold them again at a profit. Favorites were rewarded by grants of monopolies; and this evil increased until competition was destroyed and trade in almost all commodities was controlled by a few individuals, who put upon these commodities whatever price they pleased. Such common articles as salt, iron, powder, vinegar, bottles, oil, starch, paper, etc., were the subject of monopolies.

Grants of this character took from the people rights and privileges which they had before enjoyed, and were consequently odious monopolies; and the burden of them became so great that in the reign of James I (1623) the famous Statute of Monopolies was finally enacted by the British Parliament, and the King was forced to sanction it. By this statute all past monopolies were abolished, and the power of the King to grant others was expressly denied, except where such grants had been or should be made to inventors of new manufactures, conferring upon them for a limited time the exclusive right to practice their inventions.

Prior to the enactment of this statute two classes of monopolies, widely different in both their legal and intrinsic characters, had been granted in England. The first class, and the earliest to be granted, comprised those which conferred upon the inventors of new manufactures, or the introducers of a new trade into the realm, the exclusive right of carrying on that trade or manufacture

for a specified period. The English courts always sustained these grants as the proper and legitimate exercise of the royal prerogative.

The second class deprived the public of the right to make or sell those things which before the grant they had the right to make or sell. The grants of this class were always treated by the English courts as odious and void at common law. But, since the courts had no power to prevent the crown from making such grants, they could only punish the monopolist for procuring them and prevent him from exercising them; and these things they invariably did when occasion offered itself.

This statute, therefore, merely enacted into statutory law those principles which the English courts had always declared to be the common law of England.

The framers of our Constitution were well acquainted with those principles and with the reasons which induced the English courts to sustain grants of special privileges to inventors. They recognized both the justice of such grants and the advantages which wise patent laws would bring to the public, and they therefore incorporated into the Constitution that clause which I have quoted.

Acting under the authority thus conferred, one of the early acts of Congress was to pass the first patent statute, which went into effect April 10, 1790, and was entitled "An Act to promote the progress of useful arts."

The Act of 1790 specified the subjects for which patents might be granted as the "invention or discovery of any useful art, manufacture, engine, machine or device, or any improvement thereon not before known," and patents were granted for fourteen years. The act remained in force about three years, and only fifty-five patents were granted under it. The first patent granted under this act was dated July 31, 1790, and was granted to Samuel Hopkins for making pot and pearl ashes.

On February 21, 1793, another act took the place of that of 1790. Under this act the applicant for a patent was required to make oath that he believed himself to be the true inventor. This was not required under the Act of 1790.

By an act passed February 15, 1819, an important change in the mode of administering and enforcing the patent law was introduced. Under the previous acts all suits for infringement of letters patent were necessarily suits at law for damages. Under the Act of 1819 the Circuit Courts of the United States were given jurisdiction in equity, as well as in law, of actions for the infringe-

ment of patents, with power to grant injunctions to prevent the violation of the rights of the inventors. No other provision for the protection of the rights secured by patents has been so effectual as this power to restrain infringements by injunction. It is constantly invoked. In fact, nearly all patent suits for many years have been suits in equity asking for an injunction, among the other reliefs prayed for. Without this right of granting injunctions the courts could not practically secure to inventors the exclusive right to their inventions which is contemplated by the Constitution.

By the Act of 1832 the right was conferred upon a patentee to reissue his patent, provided the patent is inoperative or invalid for certain reasons stated which arose through inadvertence, accident or mistake, and without any fraudulent or deceptive intent on the part of the inventor. The reissued patent was to remain in force during the unexpired term of the original patent. This right to reissue a defective patent has been retained in all of the subsequent acts, with no substantial change in the conditions prescribed.

During the period of a little more than forty-six years after the enactment of the first patent statute, in 1790, the number of patents granted was a few over 6000, a number now greatly exceeded in every period of four months. During the past forty-six years the number of patents granted is over 600,000. The greatest number of patents granted in any one year prior to 1836 was 751. The number granted in the last twelve months is over 20,000.

In 1836 all of the preceding acts were repealed, and a new act was passed by which was inaugurated a new system for the granting of patents. The Act of 1836 introduced a radical change in the patent law, so far as it related to the granting of patents. It created an office or bureau to be called the Patent Office. The act provided for the appointment of a Commissioner of Patents, who was required to superintend and perform all duties touching the granting of patents. The conditions under which an applicant was to be entitled to a patent were substantially the same as under the Act of 1793, except that foreigners were placed on the same footing as citizens in all particulars, except as to the amount of fees paid. The term for which patents were granted was, as under the previous acts, fourteen years; but an important innovation was introduced in favor of patentees. Provision was made for the extension of a patent upon the expiration of the term for which it was originally granted for a further term of seven years, if it should be made to appear that a patentee had failed, without

neglect or fault on his part, to obtain a reasonable remuneration for the time, ingenuity and expense bestowed upon the invention, having due regard for the public interest. The right to the extension of a patent was taken away by the Act of 1870, by which act also the original term of a patent was made seventeen years.

Another important feature of the patent law introduced by the Act of 1836 was the provision for the registration in the Patent Office of assignments of patents or individual interests therein, and of all grants of exclusive rights to an invention in specified territories. This change gave a security to the title of a patent similar to that given to a title to lands by a registration of deeds.

The most important change, however, introduced by the Act of 1836 was the power given to the Commissioner to decide whether an applicant was entitled to a patent under the provisions of the statute. In discharge of this duty it was incumbent upon him to make, or cause to be made, an examination of the new invention for which a patent was asked. If, on examination, it should appear to him that the invention had not before been made in this country, or that it had not been patented or described in a printed publication, and had not been in public use or on sale with the applicant's consent or allowance prior to the application, the Commissioner should, if he deemed it sufficiently important and useful, issue a patent therefor. No such examination, to be made previous to the issue of the patent, had been called for by the previous acts or by the law of any other country. It has proved to be one of the most valuable and important features of the patent system, and, in one form or another, it has since been provided for by many of the nations which grant patents for inventions.

Under the Act of 1793 a patent was granted to an applicant if he made oath that he believed that he was the first inventor of the invention. If he was mistaken his patent was void when the mistake was shown. It is obvious that in most cases it would be impossible for an inventor to know with certainty what had been done before, and the expense of an examination of the state of the art would be too great for most if not all inventors. Without such examination no purchaser of a patent could feel any assurance that the patent would not prove to have been anticipated, and under the Act of 1836 it was made the duty of the Commissioner of Patents to make the examination which the inventor in most cases could not make himself. The cost of the examination was covered by a fee of $30, which the applicant was required to pay. To provide facility for the examination, the act provided for the establishment of a library of scientific books, and appropriated $1500 for its

acquisition. This library has grown now to contain nearly 60,000 volumes.

It is true that the examination thus provided for was not to be conclusive, and a patent might be found to be invalid notwithstanding the examination. A defendant in a suit has the right to show, and often does show, that a patent is void for want of novelty or invention; but, though the examination is not conclusive and binding upon other persons, it is valuable both to inventors and to the public. The records show that nearly half of the applications for patents which have been made during the past five or six years have been rejected because the supposed inventions were found not to be novel. Under the old practice patents would have issued on all these rejected applications without benefit to the inventor, and to the annoyance of the public. The strong presumption which the examination furnishes that the subject matter of the patent is new, and that the patent is therefore valid, gives a value to it from the moment of its issue which it would not otherwise have, and increases very much the security of the investment of money in it. Very few inventions can be made profitable without a considerable outlay. Few inventors have the necessary money to develop an invention and place it upon the market, and few men who have the money could be induced to invest it in a patented invention except for the confidence which this system of examination gives in the validity of patents.

Another important duty imposed upon the Patent Office by the Act of 1836 was the power to investigate the claims of two or more inventors to the same invention, and decide which was the first inventor. Cases of this kind, known as "interference cases," often arise.

Another important change in the patent law was introduced by the Act of 1839. Under the Act of 1793 the inventor lost his right to a patent if the invention had been known or used by others before he made his application. To avoid the risk of having the invention put into use by some one else, and thus losing it, he was compelled to make his trials in secret. Sometimes the nature of the inventions made this impossible. The Act of 1836 relieved him from the liability to loss from the use of the invention by others *unless* it was with his consent and allowance. But, in order to give an inventor the opportunity to test his invention by actual use without risk of his losing his right to a patent, the Act of 1839 provided that no use of an invention by the public, either with or without the consent of the inventor, should deprive the inventor of his patent unless the use had been made for more than

two years, or upon proof of abandonment. The Act of 1836, with the amendments of 1839, virtually determined the character of the patent law as it exists to-day.

There were no substantial changes in the patent laws after 1839 until 1870, when, as before stated, the term of a patent was changed from fourteen to seventeen years.

Last year the patent laws were again amended in some substantial respects, and the amended law went into effect on January 1, 1898. Before that time the first inventor was entitled to a patent for his invention, provided it had not been in public use or on sale in the United States for more than two years before he filed his application. Under the new law he loses his right to a patent if his invention has been patented abroad, or has been described in any printed publication in this or any country more than two years before his application is filed.

Another provision of the new law relates to the effect which a prior foreign patent has upon a United States patent. Under the old law a patent granted in the United States for an invention previously patented in some other country would expire with the first expiration of a foreign patent. This law sometimes worked great hardship to American inventors in this way. It takes a long time for some cases to secure the allowance and issue of a United States patent, while in many of the foreign countries the patent is granted very soon after the application is filed. The inventor ordinarily desires to exploit his invention in this country as soon as possible, and generally begins to do so, at least, as soon as he files his United States application. The public thereby gained the knowledge of the invention. In some of the foreign countries the laws permit the granting of a valid patent to the first applicant. In England whoever first introduces into the realm the knowledge of the invention is regarded as the inventor, and he is entitled to the patent to the exclusion of the man who originated the invention. Any one, therefore, who learns of an invention in the United States may obtain the patent therefor in England and some other countries if he makes application before the real inventor does.

The American inventor was therefore between the Devil and the deep sea. If he did not apply for his foreign patents until his United States patent was about to issue some stranger might in the meantime apply for such foreign patents, and the real inventor's rights to such patents would be irretrievably lost. Or, if, to prevent the loss of his foreign patents, he applied for them before his United States patent was ready to issue, the foreign patents might be granted first, and that would cut down the term of the United

States patent. To relieve the inventor from this predicament the new law provides, in substance, that a United States patent shall remain in force for seventeen years, provided it is applied for before or within seven months after the first foreign patent is applied for. The law also provides that if the United States patent is not applied for until more than seven months after the first foreign application is filed no valid United States patent shall be granted.

Other changes in the law are under consideration by the Patent Committees of the two Houses of Congress. Fifteen bills of importance, and more than that number which are not important, have been introduced in the House and Senate, and probably some of them, after going through the committees' hands, will come up for action during the present session of Congress. When I began to prepare this paper I intended to refer to the more important bills and thereby to provoke discussion as to their merits, but the consideration of the past and present demanded so much space and time that I was forced to abandon the consideration of the possible future. As it is, the paper is longer than I intended to make it, and I feel that I owe you my thanks for your prolonged attention. I will close with a short quotation from one of the annual reports of the Commissioner of Patents:

"The place of the Patent Office among Governmental agencies is as unique as it is important. It is concerned neither with the collection nor the expenditure of the ordinary public revenues. Unobtrusive and unsensational in its work and methods, it asks nothing of the Treasury excepting moneys which its patrons contribute, and nothing of Congress excepting measures to secure its highest efficiency. As it enters upon the second century of the system which it administers the distrust which has existed to some extent of its functions has happily passed away. The triumphs of American invention have attracted universal admiration, and the conspicuous demonstration of their importance and usefulness has turned distrust to confidence. I verily believe that no law or legal system in any age or any land has ever wrought so much wealth, furnished so much labor for human hands or bestowed so much material blessing in every way as the American patent system."

DISCUSSION.

Mr. W. R. Warner.—I should like, from Mr. Thurston, some information respecting the patentability of a combination of a patentable invention with one the patent on which has expired. For instance, plumbers use a small oil torch, about as large as a quart cup, and with a handle on one side, and the patent on this

has expired. This torch gives a hot but non-luminous flame. In the patented Welsbach burner a mantle becomes incandescent by being suspended over such a flame. Now, if these two were combined, making an incandescent oil burner, would the combination be patentable?

Mr. Thurston.—I should say not; but possibly some modification of it might be.

Mr. Warner.—There is an invention which, as I understand it, combines just these features. It gives a light a little more brilliant than the incandescent, and is quite a taking thing, but it forms a combination of two inventions the patents on which have expired.

Mr. Thurston.—In order that anything may be patented it must be new; it must be useful; it must be something invented, in contradistinction to the work of an artisan or workman. Such a combination as Mr. Warner has mentioned could be made by any one.

A combination patent is as good as any other provided the claim does not contain superfluous elements, without which the same result might be obtained. A combination embraces a number of elements, all of which co-operate to secure a certain result; but if these elements in the combination do just what they did separately, and no more, the combination is called an aggregation, and is not patentable.

Mr. Osborn.—What I understand to be the combination mentioned by Mr. Warner is now in use in Belgium. It is claimed that it is patented here.

Mr. Thurston.—It might be patentable, and yet the patent might have no scope.

Mr. J. C. Beardsley.—May not a new application of an old idea be patented, or a combination of two old ideas, forming a new one?

Mr. Thurston.—One of the principal maxims of the patent law is that the new use of an old thing is not patentable. If the old things, combined in a new structure, co-operate and form a combination, that combination is patentable.

Mr. N. P. Bowler.—The Westinghouse air brake is made up of four devices, and these all co-operate, forming a patentable combination.

Thomas Jefferson had more to do than any one else in enacting such laws as he liked in reference to patents. He considered a patent as a contract between the Government and the patentee. He scanned the patent applications very closely, and but few

patents were issued. But the late courts have decided that a patent is not a contract, but a right or privilege given by the Government to the patentee.

The first Patent Commissioner was also Commissioner of Agriculture, and gave more time and attention in his report to agriculture than to mechanism.

Mr. J. C. Beardsley.—Why does not the principle of aggregation apply to the chainless bicycle?

Mr. Thurston.—I think it does. There are no patents of any scope on the chainless bicycle. Every one of them is limited.

Mr. C. O. Palmer.—I understand that in order to have a combination the parts, taken together, must produce a new and useful result, and must co-operate.

Mr. Thurston.—The parts must co-operate, but they need not produce a new result. A new combination producing an old result is patentable.

Mr. Palmer.—Patents and copyrights constitute property in ideas, and this, I believe, is not the case with anything else.

Mr. Wm. E. Reed.—I understand that in some countries an additional fee is charged. I would ask Mr. Thurston what he thinks of this requirement, and whether it would act as a restriction or as an aid.

Mr. Thurston.—In this country the tendency seems to be to make the patent cost as little as possible to the inventor. In Canada he must pay $20 every six years. In this country a curious law has been proposed, under which any inventor can secure a patent without paying any fees whatever, if he will dedicate his invention to the public.

Mr. Palmer.—If the elements of a claim are used in a manner wholly different from that intended by the inventor and contemplated in the specifications, would such use constitute an infringement?

Mr. Thurston.—The inventor is entitled to protection only on the thing he invents, but he is entitled to protection on all the uses to which that thing can be put; and if the same combination of parts covered by the patent is put to different uses, even to produce a result which the inventor never intended, that may be an infringement. He is entitled to such protection even though he do not ask for it.

LEVEES, WITH SPECIAL REFERENCE TO THE RED RIVER SYSTEM.

The Louisiana Engineering Society is not responsible, as a body, for the facts and opinions advanced in any of its papers.

By Frank M. Kerr, Member of the Louisiana Engineering Society.

[Read before the Society, April 11, 1898.*]

To begin with there is no "Red River System" yet. Many miles of levees, involving a vast amount of earthwork and costing large sums of money, have been built, in more or less continuous stretches, along certain parts of Red River, where, as a protection against overflow to rich and fertile sections of country, their maintenance has proved, by experience, to be of prime necessity. But the results so far attained, though encouraging and assuring, cannot yet well be dignified by the name of system.

The term system, to my understanding, implies such a combination or successful assemblage of co-ordinate principles as will evolve a scientific and complete whole. What has so far been accomplished on Red River in the way of a levee system is yet far from any such proud consummation of design and effect. In fact, science has so far had little, if anything, to do with it. Necessity, the mother of invention, earnest effort to accomplish the greatest good for the greatest number, cutting the garment to fit the cloth, and a general admixture of main strength and awkwardness, now and then, have so far formed the mainsprings of action in the premises.

To introduce the subject before us in accordance with approved methods, requires me, I presume, to touch first upon the geographical position of Red River, and then to depict to some extent its general features.

By reference to almost any authority on such subjects we learn that the Red River of the South has its source in a ravine at the eastern rim of the Llano Estacado, in the Panhandle of Northern Texas, and flows, first, in a general easterly direction, forming the boundary between Oklahoma, Indian Territory, and Arkansas on the north, and Texas on the south. Then, upon entering the State of Arkansas, about ten miles north of Texarkana, and reaching Fulton, Arkansas, it changes its course to a general southerly direction, down to Shreveport, La. Below Shreveport another change to a general southeasterly direction occurs, which is main-

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tained to its junction with the Mississippi River, through Old River, around Turnbull's Island, formed by a cut-off in the Mississippi River, in days gone by, just above Red River Landing, in Pointe Coupee Parish.

The ravine in which Red River rises is some sixty miles in length, its walls, composed of sandstone, ascending precipitously from the banks of the river to heights of 500 and 800 feet. The bluffs through which this ravine has in time worn itself rise abruptly from the prairie, and terminate in a barren plateau, stretching to the south and west. After leaving the Llano Estacado the river spreads out into a shallow stream, from a quarter to a half a mile in width, its waters flowing swiftly over a sandy bed. This feature of the stream varies but little until it reaches the point where it is joined by the Wachita River of Oklahoma and Indian Territory. Below this the change is radical, the river meandering, with greatly varying width and depth, from point to point, through rich alluvial bottoms.

The basin of Red River is the smallest of the great basins influencing conditions in the Mississippi Valley, covering only about 90,000 square miles, but the rainfall which it receives at times is equal to the highest of record anywhere, and, on occasion, certain localities in the basin are visited by periods of phenomenal precipitation.

The Red River so far described is some 1200 miles in length. That part of it, however, with which I can claim any degree of familiarity, I cannot say knowledge, extends only through what may be termed the northwestern quarter of our state, a length of river of about 395 miles.

This part of Red River, that is our Red River in Louisiana, presents in its length, from time to time, many greatly differing features and conditions; but, for the purpose of this cursory article on the subject, we may limit any subdivision of contrast in its characteristics to what may be called the upper and lower half of the river, the line of demarkation being in the vicinity of Montgomery.

The upper half of this river is, to a large extent, tortuous to a fault. For many miles, on different parts of its length, bend after bend follows in close succession, the one after the other; so that it is not uncommon for a boat, traveling up or down the river, to appear many times in the same field of view, or line of sight.

Along this upper half of the river, too, the section is extremely variable, and the slope steep and irregular; so that during periods of high water the flow of the stream, while always swift, is

frequently subjected to severe shocks, the river thus, from time to time, in its course, changing from a placid stream to one of almost torrential aspect. To partly illustrate this latter statement let us look at the slope of the river during the last two extreme high waters in the upper Red River of Louisiana. These two waters were practically of about the same volume, and delivered under about the same conditions, except as to confinement, the latter being held under much better control than the former. From the State line to Alban's Canal, No. 1, a distance of 12 miles, the slope of 1892 was 0.17 per mile, in 1894, 0.28 per mile; Alban's Canal, No. 1, to Red Bayou, 5.2 miles, in 1892, 0.81 per mile, 1894, 0.32; Red Bayou to Wild Lucia, 12 miles, in 1892, 0.70 per mile, in 1894, 0.46; Wild Lucia to Cottonwood Bayou, 9.4 miles, in 1892, 0.87 per mile, in 1894, 1.07 per mile; Cottonwood Bayou to Eric's, 7.6 miles, in 1892, 0.60 per mile, in 1894, 0.92; Eric's to Pandora Bend, 13.2 miles, in 1892, 0.24 per mile, in 1894, 0.42; Pandora Bend to Shreveport, 9.4 miles, in 1892, 0.68 per mile, in 1894, 0.48; Shreveport to Knox Point, 36.3 miles, in 1892, 0.61 per mile, in 1894, 0.57; Knox Point to Loggy Bayou, 27.1 miles, in 1892, 0.29 per mile, and in 1894, 0.51. The lengths of river thus referred to are those included in the partly leveed portions of the Caddo and Bossier Levee Districts, and similar irregularities in the high water slope of the river prevail in other parts of it.

Tortuous in direction, as stated before, its banks friable and sensible to friction, and its bed in many places trammelled with obstructions, causing violent disturbances, it is, therefore, not surprising that erosion of its banks is common, and any number of concave bends exist in which caving is extensive. Cut-offs, too, often occur, again tending to disturb conditions to the detriment of the regimen of the stream.

I suppose most of us know what cut-offs are, but for those who may not I will try to describe what they are and how they are brought about.

When the sides of two bends, forming a point of land on the river, are affected by caving, the result is the narrowing of the space separating the stream between the points of attack, until a neck is formed, which, with a continuance of adverse conditions, grows thinner and thinner, until the neck is finally worn through, causing a breach, or cut-off, through which the river forces its way, abandoning its longer and consequently flatter course for the shorter and temporarily steeper one. Numbers of these cut-offs have occurred in Red River, and have no doubt, between given

points, materially lessened the length of the river in its many years of existence.

The lower half of the Red River with which we are dealing is generally less tortuous than the other half, its section larger, and its general conditions more stable. What the lower half has, however, gained over the upper half in these respects, it has largely lost in others, principally in wasted energy, affecting more directly navigation, during periods of low water, than the subject we have at present particularly in mind.

The main tributaries of Red River enter above our State line from Oklahoma, Indian Territory, Arkansas and Texas. In fact, after entering the State of Louisiana it cannot be said to have any tributaries of any moment, in the broader sense of the word, until it is joined by Black River, only about thirty-three miles above its mouth.

It is true that, at times, a chain of lakes carries the drainage of a considerable area of country, lying between Jefferson, Texas, and Shreveport, La., into Red River, through Twelve-mile Bayou and Cross Bayou, just above Shreveport, returning also through the same channels, and to the great detriment of Red River, quite a volume of overflow water which escapes from the main river, through an unleveed portion of its banks, some eight miles in extent, about three miles below the State line; that Loggy Bayou, at times, also pours into it quite a volume of drainage water from the Lake Bisteneau region, below Minden, La.; that Bayou Pierre, under certain conditions, also tends, at its lower end, to swell the proportions of Red River to a considerable extent, but these are not by any means the sources of supply from which its high waters come, and oftener furnish escapes of considerable proportions for high water rather than appreciable additions at any time to its volume, except locally.

There have been numerous lapses in the continuity of both of the banks of Red River, but with very few exceptions and at odd times these openings have been outlets from and not inlets into the river, and nearly all of these are now closed by levees.

Some two or three of these may never be closed, as they are located at the extreme lower ends of small basins, and their closure would interrupt the drainage of these areas, now permitted during periods of low water in Red River, except by means of extensive and costly pumping plants.

As to its name, Red River, it is derived from the color of its bed and waters. Of course, its bed is not a decided red throughout its section and length, nor are its waters so at all seasons of

the year; but with shades varying from deep carnelian to dull Indian red, contrasted now and then with strata of white sand and pockets of yellow ochrous earth or clay, the general tone of the whole is always sufficiently decided to justify the appellation. The intensity of color in its waters is, of course, proportionate to the amount of red silt carried, which varies greatly with the seasons, the volume of water in motion, and the ability of the stream to retain the silt in suspension.

In reflecting about Red River I cannot help picturing to my mind three very distinct and greatly differing rivers, one of the past, mostly traditional, an octopian affair, reaching out in all directions with innumerable feelers to prey upon the valley; one of to-day, a very much matter of fact affair, largely impressed by force with a sensible appreciation of bounds and of the rights of others; and lastly, one of the future, when by continuous proper treatment and permanent control it may be "a thing of beauty and a joy forever."

The Red River of the past was a stream of spasmodic effort, erratic character and willful tendencies. Its channel, from time to time, shifted pretty much all over the northwestern quarter of the State. In periods of flood it practically occupied the whole of the valley, and at certain stages of such periods, as well as during minor freshets, it bore upon its bosom vast quantities of drift of all descriptions, and parts of this, lodging here and there, formed jams in channels of previous passage, forcing the next flood waters, freighted anew with drift, to find other routes, in many of which jams were again formed, diverting the waters again and again. In this way a vast network of streams, active and passive, was created in the valley of Red River. These channels, following the tendency of water, like all things animate, to attack that which most readily yields, to travel the smooth rather than the rugged path, to run down rather than up hill, were also very sinuous. To such an extent was this the case, and so numerous were these devious outlets that their bends were often in such close juxtaposition that when the floods came rushing broadcast down the valley, they readily broke one into the other, forming cut-off upon cut-off, abandoning their former beds in the bends and leaving them here and there in the form of odd-shaped lakes. In this way we find evidences of the wanderings of Red River from the State line to the lakes of the Atchafalaya River region, and for miles and miles east and west of the main stream.

One of the most prominent features of this period of Red River's struggle for right of way, and its arch-enemy to progress,

then and for many years after, to an appreciable degree even as late as 1885, was the great raft, extending at one time and then another from a point some fifty miles above Shreveport down as far as Grand Ecore, and even somewhat lower, at one time, probably, covering a length of river of upwards of 200 miles.

Of course the raft did not consist of one continuous jam for this entire distance, but compact jams of large proportions and many miles in length occurred at intervals, with stretches of clear channel between. So great was the obstruction wherever this raft existed that passageway by water could only be had by lateral outlets and canals around the raft, connecting the pools of water in the main bed of the river.

In addition to the visible raft in the bed of the main stream and of its outlets, the caving banks, and the lowering of the low water line in the river which has occurred in late years, demonstrate that a very large part of the alluvial soil of the valley rests upon a vast raft of timber arrested in its flight to the sea in ages past. As the banks in many places cave into the river, great trees project out into the stream in innumerable numbers, and as the low water line goes down drift heaps and forests of stumps come constantly to the surface.

Not all this buried timber and upright trees and stumps is, however, due to drift, borne from higher latitudes; much of it is of purely local origin, having grown just where it was found, and having been alternately covered by alluvium and then exposed again by the shifting of the river bed in the effort of its waters to get around and past obstructions.

The next great obstruction in Red River is the falls at Alexandria, 117 miles above the mouth of the river. They are a relic of the past, still very much in evidence to-day. This obstruction, however, concerns more particularly than any other the problem of navigation during periods of low water. The falls cover a stretch of something like half a mile in length, occupying in their length the entire bed of the river. They have a drop of about three feet, at low water, above Bayou Rapids, with two rapids some little distance above having a drop of about one foot.

The rock forming the bed of the river at the falls consists of an extremely soft and friable sandstone slightly impregnated with marl.

Various methods to overcome this obstruction have been proposed,—namely, to build a lock and dig a canal around the falls; to open and enlarge Bayou Rapids; to remove the falls or cut a channel through the rocks, and to contract the water way by wing

dams. Of all of these methods that of removing the falls naturally meets with most favor, and the only attempts so far made to improve them have been in that direction by cutting away a portion of the top, and also by cutting a narrow channel through the rocks.

During the latter part of the "late unpleasantness" between the North and the South the Federal fleet, operating with the army on Red River, was caught by low water above the falls, and extricated from a most perilous position by an engineer of the army corps, named Bailey, who built a dam across the lower falls, and wing dams upon the upper, locking the water over the falls, where he concentrated the fleet, and at a given time opened the dam and rushed it through the gap.

Very much the same method, on a very much smaller scale, of course, is, during periods of extreme low water, often resorted to by steamboat men to wash out a channel through and deepen the water over sand bars which exist in quite a number of localities where the carrying capacity of the river has been impaired by local conditions.

The removal of the falls is opposed by some on the grounds that it would involve still greater danger to navigation above by permitting too great an escape of water at low stages, claiming that the obstruction acts like a dam and retains a depth of water in the river above that could not otherwise be expected. But Red River being a sediment-bearing stream, the check given to its current by the back water from the falls must tend to cause deposit over the entire distance of retardation, and it is more than probable that the effect of the falls is to gradually shoal rather than to deepen the water above. The removal of the obstruction should, on the contrary, so increase the slope and current as to wash out the alluvial deposits.

The Red River of the past, during periods of great floods, as stated before, occupied practically the whole of its alluvial valley, except, possibly, a narrow strip of land probably not more than a hundred yards or so in width, forming the banks proper of the main stream.

As we all know, the greatest deposit of sedimentary matter occurs where the velocity of the stream carrying it in suspension is first interrupted; so that when the water in such a stream rises to an elevation overtopping its banks a continuous line of interruption corresponding in direction to the course of the bank follows, and here the first and greatest accretion from deposit is made, year after year, the land next to the river receiving less and less

deposit in proportion to its remoteness and the amount of obstruction encountered, until a point is reached inland, usually in the swamps, where practically only clear water prevails, except in special cases influenced by local conditions. In this way the banks proper of all streams, large and small, in the valleys of sediment-bearing rivers, like Red River, are higher than the contiguous country, the land sloping generally from and not toward the stream.

All but this ribbon of bank, and a high plateau here, a group of hills there, or a bluff now and then, was hidden beneath the surface of the floods characterizing the history of the Red River of the past.

The Red River of to-day, and it is with it that we are most concerned, may, in my mind, be reckoned as a shining example of the survival of the fittest. It is still more or less in a state of transition and is not yet, through all its length, an ideal stream by any means, but for the better part of its length it certainly now follows a fairly well-defined course, as compared with the past, governed here and there by levees, and, at intervals, by its natural banks, rising, with varying margins, above the general plane of high water. And here let me direct attention to the fact that along those parts of Red River where the natural banks have, within the memory of man, been above high water, and unbroken by outlets, the channel is practically free from obstruction and the high water plane of one flood stage presents little if any violent contrast to that of another of equal proportions. In fact, the natural banks perform the same good offices there that the levees do on the other less favored parts of the river.

This conversion of the Red River of to-day from a bad to a better state is being brought about not by any self-imposed sense of duty and right on the part of nature, but by control, and consequent development.

This control is being effected through channel work by the United States Government, and levee building by individuals, the State and the Levee Districts; and the development of the stream which is following is the Q. E. D. of the principles embodied in the treatment.

The channel work so far prosecuted by the United States Government has been principally in the nature of removing rafts, jams, snags, wrecks, leaning and projecting trees, etc., and, latterly, in assisting the local authorities to some extent in building levees, recognizing that the confinement of the waters of the river to one main channel was a prime factor in ultimately securing the rectifi-

cation of the river for purposes of navigation, as well as for relief from overflow. The recommendations of the engineers of the United States Government annually urge larger appropriations for the purpose of levee building, revetting banks and constructing jetty walls, to reduce the width of the river and restore its energy where bays out of proportion to the generally required section of the stream exist.

Of course in the earlier days of Red River, when its population was small, and its general conditions, material and social, were primitive, overflows were not affairs of such serious consideration as in the present day when the valley is alive with humanity and teeming with its world of interests. Those who occupied the valley in its earlier days improved and cultivated only the high banks next to the river; that is, the narrow strip which, except in very extreme floods, remained above water, as before explained. But, as time went on, reports of the prosperity of its settlers, in spite of their struggle with floods, spread beyond the confines of the valley, and it became invaded year by year by new promoters in agricultural and commercial pursuits, until all the front lands were taken up, and attention was per force directed to the back lands, which were annually submerged many feet deep by high water.

First, some outlet from the main stream was closed by parties in immediate local interest to limit to a certain extent the period of direct submergence from the river. Then the line was in time extended, here and there, over low banks, until after many years the work passed beyond the compass of individual ability. Then followed, spasmodically and sparingly, State aid. In this way, by individual effort and limited assistance from the State, many detached lines and stretches of levee, of uncertain location and dimensions, were built along parts of Red River. The partial success of these tentative barriers against overflow finally suggested bolder and better steps, resulting in the organization of levee districts with boards of local commissioners empowered to raise revenues to devise plans for and to build and maintain comprehensive levee systems for the east and west banks of the river, from the State line to the lower limits of the parishes of Caddo and Bossier, and the west bank from Alexandria to the Avoyelles Prairies.

The principles involved in the construction of levees on Red River do not differ materially, if at all, from those in practice for levees elsewhere. To get them high enough to afford a reasonable sense of security against being overtopped by succeeding floods, and wide enough at the crown and base to include a section of

earth sufficient to resist pressure with some degree of certainty have so far constituted the main parts of the formulæ governing their dimensions. In this way an embankment averaging generally three feet above the water of highest local record, with a crown six feet wide and a base equal to six times the height plus the width of crown, and banquettes of prescribed widths and heights where the levee crosses depressions much in contrast with the general surface being leveed, has been erected in the Caddo Levee District, from Blanton's Bluff, Ark., to the lower side of Sale and Murphy Canal, a length of levee line down Red River of 3 miles; from a point about 3 miles above Red Bayou to Hurricane Bluff Plantation, 22.5 miles; from the upper side of Bayou Pierre to the upper side of Tones Bayou, 12.5 miles; from a point on Bayou Pierre 9 miles below Tone's Bayou to the lower limit of the parish of Caddo, a length of line up Bayou Pierre and Tone's Bayou and down Red River of 36 miles. This aggregates a length of levee of 74 miles, leaving gaps in the line from Sale and Murphy Canal to about Hervey's Slough, Hurricane Bluff Plantation to Shreveport (except some little levee work of extremely small dimensions by private individuals), and at Tone's Bayou, aggregating about 35 miles.

In the Bossier Levee District a continuous line of about the same character extends from Hurricane Bluff to the Buckhorn Plantation, a distance of about 55 miles by the levee line, leaving only about 12 miles of the district at the lower end unleveed.

The levee line in the Red River, Atchafalaya and Bayou Boeuf Levee District on Red River begins at a point on Bayou Rapides about 2.5 miles above Alexandria and extends to Laborde's on Red River, about a mile above Bayou Choctaw, which is just above the Avoyelles Prairies. The length of this line is 37.5 miles.

Of course this does not constitute all the levees on Red River in Louisiana,—only those in the incorporated districts,—for there are many detached dikes, closing outlet bayous and short stretches of levee in a number of localities important only to the individual, or small communities, protecting territory too small to form part of a general system, or not yet incorporated in levee districts engaged in the establishment of public systems.

To ultimately perfect the system in view and reduce the chances of accident, to which it may be subjected, to a minimum, much thought has yet to be given to extension, location, grade and section.

In a river so sinuous as Red River, and one started on such a

career of development, as in the upper half especially, locations possessing anything like a fair tenure of life must ever be difficult and uncertain, until all parts of the stream have developed in section sufficiently to perform the work with which the river is charged, and those parts of it which cannot recognize when they are large enough and those which persist in surrendering to caving are regulated and made stable by revetment.

For many a day to come will it be the same on Red River; the only possible chance for safety in a line of levee against caving banks lies in distance, many of the lines located within the past six years, from 500 to 1000 feet from the bank, being already threatened at an early day by encroaching river banks. The extent to which the improvement in the grades and sections of the levees in the Caddo and Bossier Levee Districts must eventually be carried is still more or less uncertain. But from such observations as have so far been permitted it is not too bold to venture the assertion that the grades to which it has so far been possible to build them in these two districts will, for the most part, prove fairly sufficient against any such floods as have so far visited the valley, except possibly on certain stretches of the river where its development has not yet reached as promising a stage as on others; while in the Red River, Atchafalaya and Bayou Boeuf Districts it may be unhesitatingly said that a good margin of safety for its levees on Red River against future floods has been reached if properly cared for and maintained.

For a long time it appeared to the greater number of the people on Red River that the only chance of exemption from the disasters of overflow rested in each one having the crown of his own particular line of levee somewhat higher than that of his vis-à-vis, on the opposite side of the river, and to back up the theory with a shotgun during the period of high water. But that kind of sentiment has now passed, thanks to more and better levees.

I have several times referred to the development of Red River, which no doubt demands some illustration. I doubt if there exists anywhere any instance of enlargement in width, and increase in depth, due to successful confinement, that can compare with what has occurred on the upper half of Red River in Louisiana. A glance at the blue print of that part of Red River known heretofore as "Little River," accompanying this paper, will show you a contrast between the size of the river before and since channel improvement and confinement by levees that cannot well be improved upon nor gainsaid. To further illustrate this fact, I cannot do better than quote from the report, for 1894, of Major J. H.

Willard, Corps of Engineers, U. S. A., in charge of internal improvements on Red River, viz.:

"The bottom of Red River in the raft region above Shreveport has gone down as much as fifteen feet, the low water line following it to a certain extent, and a similar process has been going on below, especially in the stretch known as Little River. The effect has been to lower the general low water limit, increase the depth and give a greater carrying power to the whole river. It might be expected that the high water line should follow the general improvement, but the development of the valley, denuding it of timber and the accompanying reclamation of lands by drainage, have changed the conditions to such a degree that the rainfall is no longer held back to filter through the soil or drain slowly into the river, but it is precipitated into it with a rush, so that while the total flow may be about the same one year with another, the amount discharged per second in time of flood is far greater than formerly.

"A high water of 35 feet on the Shreveport gauge now means a volume of discharge that could not have been carried by the river in 1849, 1866 or 1874, noted high water years that old settlers refer to. One has only to examine the old channels now cut off, like Lattier, to judge how inadequate the section of discharge would have been even for a flood of far less volume than those of recent years. The abandoned channels have not changed, except perhaps to widen slightly from the wash of local rains; certainly they have not closed in, as may be judged by large old trees that mark the opposite banks; but they look so small as compared with the main river that it seems hard to believe that they once formed part of it and were navigable at certain stages by the large side-wheel boats of those days.

"The gradual closing of outlets and the building up of the levee system, now fully under way, must combine with the speedier delivery of the rainfall to keep the high water line up until the river shall have scoured a channel large enough to carry it, and then we may expect a gradual reduction of flood heights, provided means are taken in time to prevent waste of energy in caving banks and consequently diminishing the slope below a proper working limit."

My personal observation is that the low water line at Shreveport has dropped from two-tenths of a foot below the zero of the gauge in 1890, to five and a half feet below the zero of the gauge in 1894. During all these years navigation on Red River, such as it is in periods of extreme low water, was as good as, if not better than the years preceding, when the low water line was above the zero of the gauge,—in some years as much as three feet,—and what was true of the years here cited has been equally so for the years which have since followed.

High water is not of annual occurrence on Red River. Sometimes as many as four and five years elapse without high water of any moment. Nor is the period of high water on Red River very long, rarely exceeding a fortnight; but then again as many as four serious freshets have been known to occur within one year.

The principal reason for the long periods between extreme high waters on Red River, which so often occur, is due to the fact that there is during most years a striking contrast between the precipitation in the upper and lower portions of the basin.

The precipitation in the lower portion is, in the greater number of years, largely in excess of that of the upper. But in some years this upper portion is visited by heavy rains, swelling all its streams to large proportions, and pouring a vast volume of water into Red River. When this occurs at one and the same time as the annual heavy precipitation common to the lower portion of the basin, then the whole length of the river is tested to its utmost capacity, but when it has only the rainfall of the lower portion of the basin to contend with, as is most often the rule, its ability to dispose of its burden is but little tested.

On the lower portion of Red River, too, that is that part of the lower portion between Alexandria and the mouth of the river, the stage to which high water may rise is appreciably influenced by the stage of the water in the Mississippi River.

In building levees on Red River considerable care has of late years been given to details.

Stripped of some of its verbiage, and rearranged so as to illustrate that which, under any circumstances, is obligatory, that which is required unless otherwise directed, and that which must be done only when directed, the specification prescribing the mode and manner of constructing the levees on Red River reads as follows: First, things which must be observed, under any circumstances,—namely, the removal of all trees, stumps, logs, roots, stalks, weeds, grass, trash and perishable matter of every kind, over the entire surface to be covered by the levee; the plowing or spading up of the ground to be covered by the levee; the grubbing up by the roots of all trees coming within the base of the levee, and for a distance of three feet on either side of the base; the excavation of all buried logs, brick walls and other unsuitable material; the cleaning and filling of all cross ditches for twenty feet from the base of the levee, on the land side, to the edge of the berme on the river side, except where banquettes are made on the land side; the slashing of all trees, in woodland, within 100 feet of the base of the levee; leaving traverses as prescribed, across borrow-pits, with connecting ditches, and planting the entire surface of the completed levee with living roots of Bermuda grass, not more than one foot apart; second, things which must be observed, unless otherwise directed; the cutting to the level of the ground of all trees and stumps within twenty-five feet of the base of the levee on the land side; using earth only in the construction of the levee; obtaining it all from the river side and not disturbing the ground on the land side; shaping borrow-pits with slope, depth, etc.; and leaving all existing levees and parts of old levees undisturbed;

third, things which must be observed only when directed; cutting muck ditches, as directed; completing the clearing, grubbing, preparation of base, and cutting and refilling of muck ditches throughout the whole line or any part thereof before the levee is begun; cutting down trees in open land coming within 100 feet of the levee; placing earth in layers the full width of the embankment, and of thicknesses as directed; cutting openings through the old levees as directed, and digging drainage ditches on the land side of the levee, as may be directed.

The greater part of this specification explains itself, but the purpose for which a muck ditch is dug is not generally understood. As generally required it is a muck ditch only when the levee is built with scrapers and mules, inasmuch as the animals tramping over the fresh earth in the ditch tamp it down. It is probably misnamed, and should more properly be called a search ditch, for it is more generally required for the purpose of exposing any underlying defects within certain limits of the surface of the ground. Very often a most promising exterior soil covers a multitude of sins in the way of defects, such as stumps, logs and cavities. By digging a ditch, which is usually located near the center line of the levee, the presence of any of these defects to any serious degree is made known and the proper remedy is applied.

Another matter of importance in building these levees is the additional height required to provide for shrinkage. Of course the shrinkage of earth taken from pits and placed in embankment varies with different soils and the methods employed in handling them, but to insure a reasonably safe margin under any conditions of soil or method and manner of handling, the contracts for levee work on Red River have so far uniformly required that all embankments be built to a gross height one-fifth higher than the net fill established, and as the soil on Red River is generally of a sandy character and it has almost entirely been handled with scrapers and mules a large part of the line, in consequence, really stands higher than the grade generally spoken of in referring to the levees.

Once properly built and turfed the levees on Red River are less subject to accident from internal causes than almost anywhere else in the state. First of all the crayfish does not exist along its banks. Nor have I ever heard of the muskrat up there. Moles do show up now and then, but they do not disturb the embankment to any appreciable extent, simply skimming along near the surface. On the upper half of Red River, that is in the Caddo and Bossier Levee Districts, I have been shown deep holes bored hori-

zontally into the slope of the levee by the kingfisher, which might be a source of danger in high water if extending any way nearly through the embankment. And on the lower half of Red River, that is in the Red River, Atchafalaya and Bayou Boeuf Levee District, I have seen numbers of a species of mole, locally called a salamander, that can do serious injury to a levee. It is an animal about the size of an ordinary rat, the head closely resembling the rat, with keen round eyes. The foreshoulders and legs or arms are much more developed than its hind quarters and legs, and the forearms are provided with highly developed hands and long, sharp and strong claws. These it uses for digging. Another feature of the animal are a species of bags or pockets of skin just back of its ears. It digs rapidly with the hands, filling the bags or pockets with loose earth, "turns a somersault" in the tunnel it is digging, as graphically insisted upon by a local describer, carries its load to the surface and deposits it at the mouth of the opening, where gradually a small mound of loose earth is reared, by which the presence of the animal and his work is detected.

From one end of the river to the other, however, the hog finds special temptation in the levees, which he proceeds, whenever and wherever he can possibly get at them, to sample with vim and gusto. There are sweeping laws, however, against him, which, on some parts of the river, have been enforced and have summarily disposed of him and his depredations, and it will not be long before its enforcement will extend to all the other parts of the river.

In some localities travel upon and crossing over the levees are the next great abuses to which the levees are subjected, often affecting their integrity. There is, however, much law, too, on this subject, and it is to be hoped that sooner or later a just appreciation of the value of levees to them will lead communities to closely observe all these laws and force others to observe them.

As in most other communities in Louisiana great apathy in regard to levees exists among the people during the period of low water, or as long as the river gives promise of remaining within its banks; but let advices show that the river is about to assume threatening proportions, and the levees become at once their all-absorbing care, and they "hustle" around to the exclusion of all other interests to get them in proper shape. Let a crevasse occur, however, and no attempt is ever made to close it, if of any extent at all, while the water is up. The period of overflow is generally too short to warrant the undertaking.

Finally, as the hour is growing late and we are approaching

the borders of dreamland, and may permit some sway to fancy, a word or two for the Red River of the future.

The Red River of the future may be all that no one ever dreamed of the Red River of the past becoming, and that the Red River of to-day is still far from being. It can be made a stream of stable banks, ample and uniform section, gentle and regular slope, and graceful contour. Its insufficiencies can be supplied and its excesses moderated. It can have an uninterrupted water way trained to follow a given route with all digression from the main channel firmly barred.

Delusive as this may at first blush appear, it is not at all impossible. So much has already been done in some of these directions by comparatively so little when the richness of the field of operation and development and the benefits to be derived are considered that the project should not prove illusive if prosecuted with means, intelligence and vigor. The only question, to my mind is, will it pay? Can the people of the valley be brought to recognize the practicability and value of the work? If so, it will come to pass, and an all levee system with channel work over certain reaches which may be slow, through extremely local causes, to respond to other influences, bank protection and rigorous police laws, local and general, regulating the care, preservation and protection of works of public improvement, will work the miracle. And this all levee system must include the divorcement of Red River from the Mississippi River and its complete merging into the Atchafalaya River.

But, after Rudyard Kipling, I will close by saying "That is another story."

THE CIVIL ENGINEER AS A GUARDIAN OF THE PUBLIC HEALTH.

By J. B. Johnson, Member of the Engineers' Club of St. Louis.

[Read before the Club, November 16, 1898.*]

The sphere of the engineer has rapidly widened with the new applications of scientific knowledge in the promotion of the convenience, the comfort, and the happiness of mankind. The widening of this sphere has also led to a multitude of subdivisions of engineering work, and even the field of civil engineering is often subdivided. But since any civil engineer is liable to be called upon to provide means to promote the general health of the community, I shall here consider the duties of civil engineers as a class in the field of public sanitation.

Sanitary science may be said to have grown along with the science of bacteriology. While Jenner, with vaccination as an antidote for smallpox, in 1798, took the first important step in the way of prevention of disease, the means to be employed for the general avoidance of all kinds of infectious diseases could not have been formulated until the specific causes of these diseases had been found. The proof that all infectious and contagious diseases, together with several not hitherto so considered, such as malarial and intermittent fevers, are caused by taking into the system, either in the air we breathe, in the water we drink, or in the food we eat, pathogenic or disease-producing bacteria, has now been established beyond a peradventure. As soon as this is admitted it becomes somebody's duty to look well to the elimination of these ailments by preventing their causes from reaching their natural prey. On reflection it will be found that the carrying out of these preventive measures devolves largely upon the civil engineer, and furthermore, he is called upon to determine what measures will prove at once most economical and most effective in preventing the spread of these fatal maladies. Our census reports indicate that fully 40 per cent. of all deaths occurring in the United States are from these ordinary germ diseases. These are, in the order of their virulence, consumption, pneumonia, diarrheal diseases, diphtheria, typhoid fever, malarial fever, measles, whooping cough, scarlet fever, and smallpox. It will be noted that these do not include such occasional visitations as cholera and yellow fever, but only those ordinary, every-day diseases which are found with more or less frequency in almost every community.

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The tracing of all these species of sickness to the ravages of micro-organisms which are not native to the human body, but which find, in weakened or diseased systems, conditions favorable for their propagation, has created a greater revolution in our lives and is likely to be of far more benefit to the race than Darwin's and Spencer's theory of evolution, or than all other discoveries of this century combined. Second only in importance to these discoveries of the causes of infectious diseases come the various means of prevention which have already been found, most of which it is the business of civil engineers to provide. Now, I hold that if the provision of the preventive means falls within the sphere of duties of the civil engineer, *then it becomes his further duty to thoroughly inform himself as to all these causes and remedies and to lead in the work of educating the public to the point of providing the necessary legislation and funds to carry out such measures and to build such works as are required.*

Here is where the emphasis of this paper lies. I believe civil engineers, as a class, are not sufficiently informed on this subject, and, further, that those who are informed are not sufficiently zealous in leading in the campaign of education required in every community in order to get the necessary acts passed and the funds provided. Engineers are known for their extreme modesty, but modesty becomes culpable neglect when it keeps us from coming forward at any and all times to aid in forming the right kind of public opinion on these subjects.

I wish it distinctly understood that I include myself in this condemnation. We are, I believe, all alike guilty of culpable negligence in this matter. For instance, out of the 1400 active members in the American Public Health Association in 1894 there were listed but 33 engineers, only one of whom was from this city. Practically all the rest were physicians. This is a ratio of 42 physicians to one engineer who are struggling in America with the sanitary problems of the age. It may be that this is about the ratio of the total membership in these two professions in this country, but I should be surprised to learn that the disproportion is so great. As that association is doing a vast amount of good in gathering and disseminating information on this the greatest of all sciences, so far as life and health are concerned, surely it should be better supported by the engineering profession. We should remember that it is the primary duty of physicians to cure disease, whereas it is the primary duty of the sanitary engineer to prevent it. We should expect to see, therefore, a public health association, devoted to the prevention of disease, composed mainly of bacteriol-

ogists and sanitary engineers rather than of physicians. It is greatly to the credit of the medical profession and to the discredit of the engineering profession that the reverse is the case.

Let us now try to evaluate the engineer's responsibilities in these matters. You will all admit that it is solely the engineer's business to provide the drinking water, to dispose of all sewage and garbage wastes, to make healthful streets and alleys and to keep them clean. The business of heating, lighting, and ventilating large assembly halls, hospitals, school buildings, and railway stations and cars is also now coming to be regarded as the business of engineers, and soon the artificial cooling of such buildings will be added to their duties. But the census reports show that one death in every seven is caused either by a diarrheal disease or by typhoid, malarial or intermittent fevers, and nearly all these deaths are known to be caused by impure drinking water. In the year 1890 over 120,000 persons died in the United States of these diseases, and without doubt we may charge this number of deaths to the use of impure water.

It is further shown that the average annual death rate in 1890 from typhoid fever alone was the same in the large cities as in the smaller towns and country, being in both cases an average of 56 in every 100,000 persons. In 1896 this rate had fallen to about 30 in 100,000 in twenty-eight of the leading cities, owing to improvements made in the drinking water in the meantime. Thus the Chicago rate dropped from 83, 160, and 104 per 100,000 in 1890, 1891, and 1892 to 31, 32, and 46 in 1894, 1895, and 1896 respectively. This was traceable directly to bringing into service the water inlet four miles from shore in place of two miles out, which change was made in 1893. That is to say, this change in the intake of the water supply reduced the deaths from typhoid fever in that city during the three years, 1894, 1895, and 1896, from 1856 to 576, or a saving of 1280 lives annually.

If a life is worth $5000, as the laws of many States, including Missouri, have determined, then the money value of the lives saved in these years and since has been over $6,000,000 annually. If to this we add the value of the loss of time by sickness on the part of those attacked by this disease and who recovered, which is usually about six times as many as die, we have a saving of 7680 cases of typhoid sickness. If we estimate a loss of six weeks' time to each patient, and a combined money loss of time and expense of $200 for each case, we have $1,500,000 more to be credited annually to the improvement caused by taking the water from a point two miles further out in the lake.

Again, the city of Lawrence, Mass., had an annual typhoid fever death rate in 1890 of 123 per 100,000, but after the use of filters in 1892 the death rate from this cause fell off to 15 per 100,000 in 1896, or to less than one-fourth the former number.

But even this number of typhoid fatalities is large in comparison with that in many of the cities of Europe. Although in these cities the water is very often taken from very polluted streams, yet it is effectively and intelligently filtered under government regulation and supervision until practically a perfect drinking water results. Thus in 1896 the average annual death rate from typhoid fever in Berlin, Vienna, Hamburg, Munich, Hague, Dresden, Stockholm, Copenhagen, and Breslau was only 5 per 100,000, while the best American average of 16 or 17 could be made up from the cities of New York, Brooklyn, St. Louis, Lawrence and Milwaukee.

There is no American city found in the first class of European cities named above, while Atlanta, Pittsburg, Denver, and Jersey City fell in the lowest class (in 1896) along with (but not so bad as) Alexandria, Cairo, and St. Petersburg. As showing how far behind we are it need only be said that no city in all Germany is allowed to supply an unfiltered surface water to its inhabitants. Even so pure a source of supply as Lake Zurich, at the foot of the Alps, has at times been the source of typhoid fever, and now all the water coming from it for domestic uses is carefully filtered. There is, in fact, no surface water free from contamination either by man or by domestic animals, so that we should immediately adopt the one and only means for purifying these waters for drinking purposes,—viz, sand filtration. Although America has the credit, in the experiments carried out under the Massachusetts State Board of Health, of establishing most clearly the efficiency of sand filtration and the reasons therefor, Europe had long been practicing the method and reaping its practical advantages. On the contrary, while we have fully established the theory of the efficiency of sand filters, we have made little or no progress towards availing ourselves of their benefits. In this, as in many other directions, we are trusting to luck, or to the "genius of American institutions," or to the "hand of destiny" or to some such *ignis fatuus* to bring us along all right without being obliged to plan our lives and to guard the public health by means of these extraordinary precautions which "the effete nations of Europe" find it necessary to take.

While the annual typhoid fever death rate of St. Louis is now only about 20 per 100,000, in 1892-93 it rose to 103 and was con-

sidered epidemic. It is now just a year since a terrible epidemic of typhoid fever raged at St. Charles, Mo.,* *3 per cent. of the entire population being attacked and the death rate being 250 per 100,000 population.* This epidemic was traced to a local contamination of the water supply from their own sewer system,† whereas the St. Louis epidemic was not traced to any local cause. If the same proportion of citizens of this city had been stricken down with typhoid fever we should have had 18,000 cases and over 1500 deaths. What a terrible possibility this is to contemplate! Now, in the case cited at St. Charles, somebody is surely responsible. The sewage contamination was well known to the city engineer, and presumably to the other city officers. The danger arising from such contamination was also well known, or should have been.

As a sequel to a similar epidemic at Ashland, Wis., in 1893-94, a case was tried in the State courts in November, 1897, wherein the company supplying the city with polluted water was held liable for the death of the deceased in the (legal) sum of $5000. I have not heard of this case being reversed‡ by a higher court, and if it should stand it will become a leading case in making the authorities responsible for the lives of the victims of their own negligence.

If a man loses life or limb by falling into an unguarded excavation or into a cellarway on a city street he collects damages from the city. Why should he not obtain damages for disease brought upon him through the culpable negligence of city officials in any other direction? I believe he should, and I also believe we are now ready to make such suits lie against any city or private corporation furnishing polluted water to the citizens. What more right have they to sell to unsuspecting citizens a drinking water

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*A town of 7000 inhabitants on the Missouri River a few miles above its mouth.

†See article by Dr. H. H. Vinke in *The Medical News*, July 30, 1898.

‡Since the above was in type, I have learned that the Ashland judgment was reversed in the State Supreme Court, on the ground of contributory negligence. It was shown that it was common knowledge, and had been for months previous, that the water was polluted, and it was further held that the water company was only a carrier. This case would seem to clear a private corporation, but whether or not it would clear a city corporation furnishing water to its own people is another question. The private corporation could be attacked on its contract with the city to furnish pure and wholesome water, in a suit brought either by the city or by a citizen, but as it is a creature of the city government, the city itself would seem to be the proper party to look to for damages for allowing impure water to be furnished to the citizens. The case therefore does not bear the marks of finality.—J. B. J.

containing the seeds of fatal diseases than they have to sell a poisonous drug as a medicinal remedy, or to take life and health in any other way? Evidently they have no more right, and as soon as the state of science becomes such as to make certain to the minds of twelve jurymen that the drinking water was the cause of a death, and that the authorities had been warned and had reason to believe that the water was polluted, and yet continued to supply it, just so soon can the legal compensation be collected by the heirs of the deceased.

When this day arrives it will soon be discovered that preventive means cost a great deal less than the damages will amount to at $5000 per death. And then our cities will be driven to devise the appliances and our city governments to furnish the means for freeing the drinking water from these fatally poisonous germs. But does the conscientious civil engineer who knows, or ought to know, the character of the water he is supplying, and the dangers resulting from its use, propose to sit idly by till he is compelled to act as a means of economy only to avoid legal liability? Such a man should be unworthy of our respect, and yet such is exactly what all we civil engineers in America are doing as a class. One would suppose that as soon as a public official becomes satisfied that he is furnishing a polluted water to the inhabitants over whom he is placed as a guardian in this respect he surely would immediately exert himself to the utmost to have the city water taken from a purer source or purified by an efficient system of filtration. But the accomplishment of either of these ends involves the education of the citizens up to the point of acting in this matter and agreeing to pay the cost of the proposed change. In this country all improvements come from the people themselves, and hence come much more slowly than they do in a country like Germany, where a few men only need be convinced of the necessity of a given measure and it is done. All the more reason, therefore, in this country that the few who do understand the necessity of any proposed change should consider themselves charged with the *duty* of forming and leading public sentiment by all suitable means to hasten the dawn of a better day. And the civil engineer knows, or ought to know, for it is his business to know, the relation between water supply, sewerage, street and alley conditions, the condition of school premises and buildings, and the air conditions in assembly halls, in street and railway cars, in hospitals and in asylums, he knows, I say, the relation of all these to the public health, and, as the construction and operation of all these fall within his professional jurisdiction, he is in duty bound to continually do what he can to teach and lead the public in such matters.

The means of preventing the spread of disease through the drinking water is a rational or scientific filtration, such as has now been shown to be effective. The means of prevention of disease from the decay of organic matter caused by these bacterial parasites, and thence their passing off into the air we breathe, is to immediately remove all organic wastes from the confines of the city. This includes not only sewage or house drainage proper, but all garbage, street sweepings and alley filth, and the prevention of the vast and luxuriant growth on vacant lots of weeds, which are not only the cause of hay fever from their pollen-laden atmosphere, but which, in finally rotting on the ground, breed and give off other swarms of parasite germs to further burden the human system. But the rapid and thorough removal of street accumulations means a smooth, clean and impervious pavement. In place of this we find in this city, in most of the resident districts, either a mud-covered macadam or a rotting wooden reservoir and nest of all possible foulness. I believe there is no possible kind of excuse for a pavement so unsanitary as the wooden block after it has begun to decay. It not only retains nearly all the filth dropping upon it, but it becomes itself alive with those parasitic growths which constitute the decay of timber. Such a pavement is, therefore, the very quintessence of that particular kind of putrefaction and living filth of which we are to-day standing in such awe, and against which we are summoning all the devices of sanitary science. How much the city civil engineer could do if he would to prevent the further use of these abominations!

Again, the most elementary and fundamental principle of sewerage is not only to move all filth off as quickly as possible, but when once it has started it should be kept going till it passes into some large river or goes to some kind of purifying terminus. How do we comply with this provision in this city? In almost every back yard in this entire city will be found a brick privy vault into which the house drainage flows on one side, and out of which it is supposed to flow to the sewers on the other side. It is the most common experience in the world to have these stop up. The near proximity of the coal shed and kindling stall is too great a temptation to the average American child, and sticks, rags, bricks, stones and coals are continually finding their way into these catch-basins and stopping them up. In rented premises the tenant dislikes to go to the expense of having the sewer connection dug up, and commonly the owner will not do it; and so we find that they become filled, and that their contents back up into the house cellars. Often the basins remain in this condition for weeks and even months at a time.

In the report of the St. Louis Health Commissioner for 1895-96 I find that in that one year *over eleven thousand* such cases were found, the vaults being in such a condition as to be declared nuisances, and usually full and overflowing. Probably many times this number of stoppages occurred, only those being reported to the Health Department which were not promptly attended to. These primitive and absurd devices are a remnant of ante-sewer days, when they were earthen vaults or cesspools. When sewers began to be constructed these cesspools were, properly enough, connected with the sewers, but that fact did not justify the further building of them on new premises in sewered districts. And yet this filthy practice has been almost universally followed in this city, and is so to this day, without any protest, so far as I am aware, from the city Sewer Department and without any prohibitory legislation. For engineers to admit that this is the best that can be done is to acknowledge incapacity in this line of sanitary engineering.

Again, in violation of the same fundamental law of sewer construction, namely, the keeping of all sewage moving without hindrance after it is once started, we find in this and in almost every other city, at every street intersection, one or two sewer inlets for storm water and street and alley drainage which are purposely built as catch-basins or as filth depositories. We all know that these are seldom cleaned until they become clogged, and we all know, too, that each of these clogged basins contains a mass of black nastiness which is doubtless swarming with micro-organisms of all sorts, pathogenic amongst the rest. How many tens of thousands of these open pest holes we have in this city I do not know, but I find in the report of the Sewer Commissioner for 1895-96 that 9933 of them required cleaning out and that 16,145 cart loads of filth were taken from them in one year. What is out of sight is out of mind, but if the citizens of this city could but see what lies a few feet below the pavement at every street corner they would raise their hands in holy horror. To claim that these pest holes are necessary in order to keep impediments out of the sewers is, I think, invalid. I would guard these inlets by screens at the surface, and trap them from the escape of sewer gas by flap valves, and so eliminate these catch-basins which, by breeding, harboring, and giving off into the air all kinds of bacterial life, become veritable man traps. Our sewers all have an abundance of slope, and in time of storm will carry along anything that can get into them through properly screened inlets; and if it is not their purpose to carry off the abominations that stop now in these vaults a new

definition will have to be made for them. In my opinion both of these appendages to our sewer system are unnecessary, unsanitary, and uneconomical to such a degree as to warrant their abatement as public nuisances.

And now to return to the question of our drinking water. Since we use a surface water, it is of necessity more or less polluted. All running streams are open sewers in the sense that they drain the tributary watershed and carry all the offal which is removed, in solution or in suspension, by the cleansing rains. The particular character of these polluting ingredients varies constantly from season to season, and from day to day. The general fact, however, remains, to be read of all men, that we take our drinking water from the great sewer of the Mississippi Valley. Not only does it contain its legitimate amount of pollution, but in a year or two there will be added to it, a few miles above our waterworks intake, the offscourings of a city of nearly two million inhabitants, which city lies entirely outside of the Mississippi Valley, and hence is not naturally tributary to it. If it is not good law it ought to be, that in the matter of stream pollution every natural basin should take care of its own, and not change the face of nature to a neighbor's hurt. When the law was enacted for the construction of the Chicago Drainage Canal, the question of the potability of water rested wholly upon a chemical basis. The science of bacteriology was so far in its infancy that it was not yet in use as a tool for sanitary purposes. Now the healthfulness of a drinking water rests wholly upon a biological basis. We now want to know how much life there is in it, and the probable source of this life. As a chemical question we in St. Louis felt that no good case could be made against the scheme. It was then supposed that a running stream purified itself in the course of a few miles, and I see the Secretary of the State Board of Health of Illinois was quoted a few days ago as still holding to this delusion. He ought to know that, so far as the removal of bacterial life is concerned, there is probably not a river in America long enough to purify itself of typhoid fever germs when once charged with them. These germs live for weeks in comparatively pure water, and there is absolutely no possibility of a stream purifying itself from them simply by its flow. If the stream carries a large amount of sediment this is always settling out in the quieter pools along the way, and in this way it is constantly purifying itself, as a clear stream cannot do, since this sedimentation carries down also a large proportion of the micro-organisms. But to claim that they are all carried down in any known distance is to claim what no one knows

to be true, and what would seem to be very improbable from the known persistence of some of these organisms and from the theory of probabilities. In our St. Louis settling basins we do remove a large proportion of these germs, but many remain, and the only way we can remove these is by filtration. If, after settlement in our basins, so much silt still remains in the water that gravity sand filtration is impracticable, then should we not have known this long since? If the filtration of settled water will not remove the bacteria because of the sedimentary removal of those forms of vegetable life which alone can make a sand filter effective, then should we not have known this before now, or at least should we not be finding it out as fast as possible? And if one or both of these causes would make gravity filters impracticable for St. Louis there would still remain mechanical filters to be used with coagulants in conjunction with sedimentation, which, if properly constructed and operated, would doubtless perform the work.

I think a reasonable solution of these problems could be found for a moderate sum, and I believe if we civil engineers as a class, and those of us charged with the administration of the water supply in particular, should unite in demanding that this thing should be done, and done at once, there would be little or no delay. Several years ago Mr. Robt. Moore read a paper before this Club* in which he showed the necessity of filtering our water supply, but our Board of Public Improvement has as yet not moved in the matter. The city Health Commissioner has been crying loudly for years that this should be done, but I cannot find that his hands have been strengthened in any way by our civil engineers, either in or out of the city's employ.

I have tried to show that it is peculiarly the duty of civil engineers to provide clean and sterile streets; to quickly and continuously remove from streets and dwellings all natural refuse and human wastes, and to supply the citizens with an abundance of pure and wholesome water. Also, that when all these things will have been done the cases of sickness and death will be greatly reduced, the average length of life prolonged, and earthly happiness indefinitely increased. Furthermore, that it is peculiarly the duty of all civil engineers to lead in forming a public sentiment which will insure the accomplishment of these results.

I do not wish to imply conscious official or culpable private neglect on the part of any one, but I think we have all as yet declined to take upon ourselves the responsibility which has

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*Journal of the Association of Engineering Societies, Vol. XIV, p. 41, 1895.

recently come to rest upon us, the responsibility of leading public sentiment on these questions instead of waiting till this has crystallized into a particular scheme, and then, when called upon, saying how the thing may be done. Our duties in this respect have entirely changed with the new theory of infectious diseases. He is now the good citizen who foresees what *should* be done and then persuades the people to resolve that it *shall* be done. The man who really *does* it is small and weak in comparison with such a one. Why should not civil engineers be public benefactors as well as public servants?

THE CIVIL ENGINEER AND NATIONAL PUBLIC WORKS.

By Geo. Y. Wisner, Member of the Detroit Engineering Society.

[Read before the Society, December 16, 1898.*]

In April, 1888, a number of distinguished civil engineers, representing twenty-three engineering societies, having a constituency of over three thousand practicing engineers, had a hearing before the United States Senate Committee on Commerce, relative to changes in methods of conducting public works, and, in reply to the statements presented, the chairman of the committee said: "If a worse system than ours can be found on the face of the earth I would like to know it." In view of the fact that strong recommendations have recently been made to have the number of engineer graduates from West Point largely increased, so that an officer of the Engineer Corps can be placed permanently in charge of each river and harbor project, it will be of interest to know whether the statement of the distinguished Senator was true in 1888, and, if so, whether the system of conducting the public works of the country has so improved since that date as to warrant the placing of all important Government engineering projects under the control of graduates of West Point and to exclude all civil engineers from holding any positions on such works except those of a subordinate nature. If the system is worthy of being perpetuated, a fair discussion of its history and merits will give it a higher standing with public men, and, if not worthy, a thorough discussion is certainly desirable.

Previous to the present year the tendency of national progress in this country has been almost entirely along commercial lines, while our system of public works has gradually passed from civil to military control, a condition of affairs which, when compared with the systems of public works of European countries, seems somewhat anomalous.

The continental systems are strictly under civil control, and are so constituted as to secure to the Government the services of civil engineers eminent for their ability and practical experience; and have resulted in the development of men of great theoretical and practical attainments, whose works and writings are the basis of plans of many important public works in this country.

In Great Britain no Government public works organization has ever existed, and, with the exception of dock yards and har-

*Manuscript received December 12, 1898.—Secretary, Ass'n of Eng. Socs.

bors of refuge, all river and harbor improvement works are under the control of boards or trusts, who go into the open market and secure the services of any civil engineers they may choose to select.

The system is one which insures the quick completion of work when once inaugurated, prevents the starting of projects of doubtful utility and completely eliminates all danger of the "log-rolling" methods which have become one of the necessary evils connected with the passage of a river and harbor bill by Congress.

The public works organizations of other European countries are practically similar to those of France and Prussia, which are independent departments of the Government, under the direction of the Minister of Public Works.

Naturally the method of making public improvements in the early days of our republic were those inherited from the mother country, but the limited means at the disposal of corporations and municipalities, and the immense distance over which transportation facilities were required, soon made it necessary to resort to other sources for funds with which to carry on such enterprises. Aside from the Military Academy at West Point, the first engineering school in the United States was established at Troy, N. Y., in 1824, and consequently the source of supply of civil engineers for either public or private work was limited to the West Point graduates and to men who had obtained some experience in engineering as assistants on the few public works then under construction. The decision of the United States Courts at an early date limited State control over navigable waters, and practically settled for the future that the system of public works must be a Governmental one, not necessarily military; and, as the Military Academy at West Point was the only source at that time from which educated engineers could be obtained to take charge of engineering projects, it is not strange that all Government improvements should have been executed under the direction of the military engineers.

The Corps of Engineers owes its origin to an Act of Congress of March 16, 1802, by which the President was authorized to organize and establish at West Point a Corps of Engineers not exceeding twenty in number, which was to constitute a Military Academy, and to be subject at all times to do duty in such places and on such service as the President of the United States should direct.

In 1838 the corps was increased to a total of forty-seven officers, and at the same time a Corps of Topographical Engineers of about the same number was organized. There was but little

harmony in the working of these two organizations, and in 1863 the Corps of Topographical Engineers was abolished and its officers merged into the Corps of Engineers, the number of officers for which was fixed in 1866 as follows: One Chief of Engineers, six Colonels, twelve Lieutenant-Colonels, twenty-four Majors, thirty Captains, twenty-six First and ten Second Lieutenants. This organization was charged with all duties relating to the selection, purchase and survey of sites, and the plan, construction and repair of all fortifications; with all channel and river obstruction for the purpose of defense; with all fixed and movable bridges for the crossing of navigable waterways; with all surveys, plans and construction of harbor and river improvements, and with military and geographical explorations and reconnoissances as might be required for these objects, including the geodetic survey of the Great Lakes.

For twenty-two years after the establishment of this corps the West Point Academy was the only institution in the United States making any pretense at having a course in civil engineering, and it was but natural that the younger graduates of that institution should have regarded themselves as the only ones qualified to discuss problems pertaining to their profession, which opinion, as an inheritance to the graduates of that institution during later years, has probably been the indirect cause of many of their troubles.

In 1843 Prof. Alexander D. Bache, who graduated from West Point in 1825 and soon afterwards resigned from the corps, and from ability and experience having become one of the foremost scientists of the country, was appointed Superintendent of the United States Coast Survey.

Professor Bache was one of the best executive and scientific men of modern times, and Congress, impressed with the business-like methods with which he directed the work assigned to his charge, granted liberal appropriations for its prosecution, with which results of great value to navigation were obtained and a national reputation established for the department. In connection with the topographical and hydrographical survey of our coast lines an accurate geodetic survey was inaugurated, which has since developed into a system of triangulation along the entire Atlantic coast and connecting across the continent to the Pacific Ocean.

The authority granted to the Engineer Corps to make geographical explorations and geodetic surveys soon brought on a conflict with the Coast Survey, which was a discredit to both organizations, and undoubtedly was one of the principal causes for

the distrust with which the methods of conducting our national public works are regarded.

Thousands of dollars were wasted in the duplication of surveys and in the execution of work which has never been utilized, and for doing which there was no apparent reason other than to get ahead of the other department.

The fact that the Superintendent of the Coast Survey was a graduate of West Point naturally gave rise to the expectation that the organizations would work in harmony, but such was far from being the case; and in this connection it is of interest to note that a bitter feeling of antagonism exists in the corps at the present time towards ex-members of that body who have resigned to engage in the private practice of their profession.

With the rapid growth of our country since 1865, and the necessity of securing the best engineering talent available for public works, a general disposition among thoughtful men arose to protest against establishing military supremacy in matters of a purely scientific and civil nature. It was evident that to place our entire national improvements under the control of a close corporation, the members of which were culled from the graduates of a single institution and governed by military rules which prohibited advanced ideas on the part of subordinates, would not be to the best interest of the commercial and other enterprises depending for success on the rapid and economical completion of extensive river and harbor improvements.

The differences of opinion relative to the methods which should be adopted for the improvement of certain rivers and harbors culminated, in January, 1874, in a proposition from Captain James B. Eads to improve the entrance to the Mississippi River for a fixed amount of money, the Government not to be liable for any part of the cost of the improvement unless the results specified should be obtained. A few months later Congress authorized the President to appoint a commission, consisting of three military engineers, three civil engineers and one member of the Coast Survey, to visit the harbors of Europe and report upon the question of the best method of making a deep water entrance to the Mississippi River. This commission decided in favor of the jetty system advocated by Captain Eads, and which he afterwards carried out with such success as to give him a world-wide reputation as one of the ablest hydraulic engineers of the century. If the petty jealousies of some of the older members of the Engineer Corps had not been the controlling element with that body the organization might have secured much of the credit for the success

of the enterprise, and at the same time have advanced their professional standing by securing the cordial co-operation of the civil engineers of the country. Instead of this a bitter antagonism to the enterprise was engendered, which resulted in large financial loss to the contracting engineer and damaged reputations for his opponents. The time never existed when the civil engineers were not willing to cordially co-operate with the army corps, provided they could do so on an equal footing. This right was not admitted, and a struggle for professional recognition by the civil engineers and to prevent loss of control of public works by the army corps has been continued in various ways ever since. While it is to be regretted that so much engineering talent should waste its energies in professional quarrels, certain compensating benefits have resulted, due to the careful studies the advocates of either side have been obliged to give to the plans, methods and projects proposed by their opponents.

The complete failure in 1873 of the plans of the Engineer Corps for improving the entrance to Galveston Harbor resulted in an invitation being extended by the people of Texas, through their Legislature, to Captain Eads to submit a proposition for securing a 30-foot entrance to the harbor for a lump sum, payable when results were obtained.

Captain Eads complied with this request, and a bill was introduced in Congress authorizing the Government to enter into such a contract, but, owing to false representations on the part of the corps to the effect that the Government could complete the improvement for one-tenth of the amount which it was proposed to pay Captain Eads, the bill was defeated.

The work since done on this project has cost nearly as much as was asked by Captain Eads to complete the improvement, and has resulted in securing a narrow channel about 26 feet deep.

With the successful completion of jetty works at the mouth of the Mississippi River, and the general impression that any project for public improvements having its origin outside of the army corps would meet with bitter opposition from that body, many prominent civil engineers were convinced that the good of public service demanded that the entire system should be remodeled, and that civil engineers in such service should be on an equal footing with military engineers as to the control and execution of work under their charge.

At the convention of the American Society of Civil Engineers in St. Louis in 1880 a resolution was adopted to appoint a committee to draft a memorial to Congress asking that the civil

engineers of the country should be placed in full charge of improvement works carried on by the Government. The influx of military engineers into the Society during the next year was somewhat abnormal, and at the next annual convention the committee reported against the contemplated action on the grounds that it would be prejudicial to the interest of some of the members of the Society. A memorial to Congress was, however, circulated privately, to which the signatures of one hundred and sixty-eight engineers were secured, of which sixty were prominent members of the American Society. This was probably pigeonholed and possibly never read in Congress, but the agitation resulted in an invitation being issued by the Civil Engineers' Club of Cleveland to the various engineering societies of the United States to meet in convention, at Cleveland, December 3, 1885.

Ten different societies sent delegates to the convention, and, after formulating a line of action and electing a permanent Executive Board, they adjourned until March 31, 1886, when a permanent organization of delegates from twenty-three societies was effected under the title of "Council of Engineering Societies on National Public Works." A memorial was addressed and presented to the President of the United States, outlining a system by which it was proposed to secure the "adoption and execution of only those projects that are necessary and useful to commerce; the correctness of plans and economy and effectiveness in their execution, and to avoid the wastefulness of public funds in legislation and administration."

After two years of study and discussion the Council of Engineering Societies formulated their conclusions into a bill, which was introduced in both Houses of Congress January 16, 1888. This bill was carefully considered by the committees of both Houses of Congress and favorably reported, but finally died a natural death before being reached on the calendar. Under this bill the military engineers would have had a majority of the officers in the new corps, and no doubt would have controlled its methods to a considerable extent; and as these officers would have been in direct competition with some of the ablest civil engineers of the country the efficiency of the organization of the corps would have been greatly increased. This bill would have become a law but for the lack of support from the technical press, which, for reasons best known to the editors of those journals, did not at that time view the movement with favor.

The discussion of this bill resulted in some changes in the methods of conducting public works which were of much benefit

to the service, but, so far as the military and civil branches of the profession were concerned, the relations were by no means improved. District officers in charge of important enterprises were ordered to give out no information relative to the condition of the works, and to put nothing in their annual reports which could be utilized by civil engineers for the purpose of criticising their methods and plans.

This was carried so far that in one case an assistant engineer who had sufficient self-respect to report the actual condition of the works under his charge was immediately discharged.

The demand for deep water ports on the Gulf Coast was such that several private companies undertook to raise funds by floating bonds with which to execute the work, but were unable to do so owing to the adverse criticism of the projects and plans by the corps. Two of these projects were so near completion before their projectors were obliged to abandon them for want of funds that the results obtained showed conclusively that the completion of the plans would have produced better depth of channel than predicted by the engineers in charge, and yet both of these enterprises have recently been reported on by boards of army engineers as being of no value to the Government, in spite of the fact that vast sums of money were spent under direction of the corps at both of these places before being abandoned by the Government.

One of the worst features of the system is the method of handling the funds appropriated for carrying on national improvements. The clerical work necessary under the regulations is at least five times that which would be used by a good business concern in doing the same amount of business, and, at the same time, does not in any way protect the Government or the public from fraud.

It is true that the army officers are not directly responsible for the regulations under which their accounts are audited, but it is equally true that, by making no protest at the wasteful and unbusiness-like methods required on Government engineering, they become partners to the transaction. The expediency and amount of an expenditure is of little moment compared with the form of the receipt and the color of the ink used. The system is a direct bid for fraud on the part of chief clerks, who become so accustomed to doctoring the form of bills and vouchers for the purpose of having them pass the Treasury auditors that they sometimes forget where to stop. In addition to the expensive and cumbersome office methods necessitated by the system, the engineers in the field are obliged to devote a large amount of valuable time to the supervision of making out and certifying unnecessary bills and receipts.

Probably one of the greatest drawbacks to the success of military supervision on civil work is that military etiquette prohibits all criticism of opinions and plans of ranking officers by subordinates, and it is not at all improbable that the evil effects of this restriction may eventually be the cause of disrupting the corps.

Within the past year one of the most able and brilliant officers of that organization has been tried by court-martial and found guilty of conspiracy and of conduct unbecoming an officer and a gentleman, on evidence which shows that his only crime was in disregarding the red tape regulations of the department, conducting the work under his charge in a business-like manner and in successfully completing extensive harbor improvements within his original estimate. It is but fair to state, however, that a large proportion of the best engineers of the corps condemn the whole proceedings as an outrage, and state that if such a verdict can be found on the kind of evidence submitted by the prosecution in this case no self-respecting engineer in the Government service is safe from persecution.

When we consider the treatment which has been accorded projects under the direction of civil engineers by this organization it is easy for them to view this state of affairs with considerable complacency.

The case, from beginning to end, has been so peculiar that even the President has been impelled to ask as to who is behind the prosecution. No charge was made that any of the officer's funds were missing; that any of his engineering accounts were irregular, or that the contractors were ever paid one penny more than called for under this contract.

The allegation as to embezzlement arose only from the fact that, technically, any money paid out for work not done strictly in accordance with the specifications, as interpreted by the department, is claimed to be embezzled, the contention of the prosecution being that, while the quantities paid for were those actually put in the work and the prices paid actually those of the contract, the specifications of the contract were improperly interpreted by the engineer and therefore the money was technically embezzled. It was developed at the trial that the specifications and contract were approved by the division engineer and chief engineer of the corps and by the Secretary of War, and that the lowest bid was recommended to the department for acceptance and was approved by the Chief of Engineers. The work had been advertised as required by law, and the sealed proposals were opened publicly on the specified day. It was contended, however, that the materials used, namely,

the brush fascines, mattresses and stone, were different in character from those called for in the specifications, and hence that the Government had been defrauded. This, however, was not proven by reliable evidence, but, on the contrary, it was shown by a number of the ablest officers of the corps and by civil engineers of wide experience that the work was not only in accordance with the specifications, as interpreted on a large number of other important works, but that had the specifications been interpreted as contended for by the prosecution the work would have cost the Government at least $1,000,000 more than the amount it was actually completed for. This work is the only example on the Atlantic Coast where extensive improvements have been completed within the original estimates, and yet the officer in charge has been tried for embezzling the entire amount expended on the project. In this connection it should be stated that there are but few important national improvement projects in the United States, whether completed or not, which have not cost largely in excess of the engineers' original estimates.

There is no legitimate excuse for such estimates, and it is sincerely to be hoped that the investigations in New York relative to the Erie Canal improvements will make such work sufficiently unpopular that less of it will be done in the future.

Civil engineer employes of the Engineer Corps have recently been placed under the control of the Civil Service Commission. There is no doubt that, so far as clerkships in the Post Office and other departments are concerned, the protection afforded by the Civil Service Act of 1883 has been of great benefit to that vast army of officials and also to the Government service, but since in engineering matters success depends largely on the principle of "survival of the fittest" the restriction of the Civil Service rules in regard to the selection and appointment of men qualified to best do the work required and to discharge assistants when found inefficient, together with the tendency to destroy ambition, cannot be otherwise than detrimental to the service. The very fact that a man knows that his tenure of office or promotion does not depend upon the amount or quality of the service he renders often makes him inefficient. Engineers like to take the world easy as well as men of other professions, and when this can be done without detriment to position it is likely to occur.

The engineer service has never been subject to the abuses arising from political appointments, which gave rise to the Civil Service Act, and consequently there was no excuse for placing the employes under its regulations. The Engineer Corps are entitled

to much credit for having at all times resisted every attempt to subject the department to the spoils system, and, having demonstrated their ability to do this, it seems strange that they should have allowed the organization to be loaded down with unnecessary and cumbersome methods.

It is just as easy to formulate rules to prevent all undue political influence in the management of public works as to make the positions of field and office engineers independent of the officer directly responsible for the success of the work, to have appointments to important positions made by officials wholly ignorant of the work and its requirements, and to make such officials the arbiters as to whether inefficient assistants should be discharged.

It is true that the regulations are evaded by allowing work under the charge of inefficient men to be discontinued, but this is no credit to the system, for if the rules are not such as can be squarely lived up to without detriment to the service they should be either modified or eliminated at once.

The Navy Department has recently established hydrographic offices at a number of our lake cities, and its officers are engaged in making surveys and in publishing and issuing charts without regard to the duplication of similar work being done under the direction of the Engineer Corps.

A system of national public works which admits of unseemly quarrels between departments as to which shall have charge of different works; which allows the discrediting of the work of one department by another and the duplication of work and consequent waste of public funds; which promulgates such rules and regulations for its guidance that the cost of doing work and of disbursing the funds appropriated for its use is largely in excess of what it should be; whose members are liable to be court-martialed and to have their reputations and fortunes wrecked for not complying with regulations which it is probable that every officer in the corps is compelled to violate in order not to subject important works under their charge to serious delays and loss; which admits of petty jealousies relative to any river or harbor work designed or executed by civil engineers, and which it has been the policy of the organization to wreck financially if possible, would seem to embody all of the conditions summarized in the distinguished Senator's statement that we have the worst system of national public works on the face of the earth.

A military education is by no means an essential qualification for a successful river and harbor engineer, neither is it just that the graduates of our colleges and universities should be restricted in

the practice of their profession by the Government assigning all national improvements to a body of men educated at public expense. It is true that civil engineers are now occasionally appointed on engineer boards and commissions, yet assistant engineers in the United States service, although often the best qualified for such positions, are seldom so promoted, and as the experience of most engineers, outside of those who have been in the Government service, has not been such as to qualify them for the duties to be performed on river and harbor work the army officers on such mixed commissions are in a position to control to a great extent the tenor of reports submitted.

If an attempt should again be made to reorganize the methods of conducting national public works no system should be considered which does not fully recognize the ability and attainments of the members of the present corps, among whom are many engineers who if not hampered by the cumbersome system under which they serve would no doubt achieve national reputations.

During the present year the number of officers of the Engineer Corps has been increased fifteen per cent. by Act of Congress, presumably for the reason that additional military engineers were needed in carrying on the war with Spain; but that reason now no longer exists, and, if our standing army is to be largely increased, why should not the graduates of West Point attend to the fortification work, for which they were educated, and not be given a monopoly of the engineering on public improvements when the experience and education of the civil engineers and the business methods of civil life are far better adapted for securing economy and success?

If the military duties of the corps have become such that it is necessary to largely increase the number of officers of that organization, it would seem proper that at the same time the rights of the civil engineer should be recognized, and that Congress should also reorganize the system of conducting national public works so that the best practical results may be obtained at minimum expense and the ablest engineers of the country, whether military or civil, secured for the Government service.

ASSOCIATION
OF
ENGINEERING SOCIETIES.

VOL. XXI. JULY, 1898. NO. I.

PROCEEDINGS.

Civil Engineers' Club of Cleveland.

THE regular meeting was held at Case Library, July 12. Present, seventeen members and four visitors. President Osborn in the chair. The minutes of the last meeting were read and approved.

Messrs. Boalt and Culley were appointed tellers to canvass the ballots received. They reported the election, to active membership, of Robert L. Webb and Francis Henry Treat.

There was no report from the Executive Board. The chairman of the Programme Committee was not prepared to announce the title of the paper for the next meeting.

Mr. Benjamin S. Hubbell, of the firm of Hubbell & Benes, delivered an address upon the subject of "Marble *versus* Granite."

He was led to this topic by a recent study of the various marbles and granites of this country, with reference to their adoption in the construction of the Wade Memorial Chapel and Receiving Vault now building at Lake View Cemetery. The present Mr. Wade thought that the white terra cotta which is much used of late would be a suitable material, but on further reflection this was discarded in favor of stone.

The design of the building has a row of columns along the side, behind which are plain walls to which terra cotta is not well adapted, since its surface is not perfectly true. Again, with terra cotta we should require metal beams in the lintels, veneered with this material. It is true that had the building been designed in metal and terra cotta the metal columns would have cost only $60, while the marble columns would have cost $800 apiece. Nevertheless, for the sake of sincerity and good taste marble was the material selected, and it was proposed to use white marble, but we soon discovered that all white marble is not white.

Mr. Norcross recommended the Georgia marble, and so did Mr. Tiffany. This has been used in building the State Capitol at Providence and the Corcoran Gallery, Washington. The only building we know of which is really white is the Mausoleum at Detroit. This is built of Rutland marble.

The surface of marble soon disintegrates in the climate of Cleveland, and becomes granular as well as discolored. Old tombstones in the city graveyards show this, and would hardly be recognized now as marble. However, a protective fluid may be used with which new marble may be saturated, so as to become weather-proof and thoroughly durable.

We found South Dover and Tuckahoe marbles used in New York City. The Lee marble is largely used in Washington and Philadelphia, but this acquires a bluish gray tinge and the Tuckahoe turns brown. It has certain defects called "shakes," and contains some particles of magnesia, which dissolve in wet weather and leave the surface pock-marked.

The Vermont marbles were examined in the quarries and in buildings. No old marble was found in New York City that is not more or less discolored and disintegrated. The top surfaces are both rough and dark, while the under sides of projections are in good order. The Vermont quarries are probably the largest marble quarries in the world. These are at Proctor and East Rutland. The buildings of the Quarry Company are built of marble taken at random without selection. They are therefore quite mixed in color and give a really fine architectural effect. The owners were quite surprised at our admiration of these buildings.

The quarries have been excavated to a depth of 150 feet, crossing the beds of marble, which lie at a steep angle, and then have been tunnelled horizontally to cross the beds again. Several beds are found superimposed. It is seldom that a bed is more than thirty inches thick. The blocks are sawed into slabs regardless of the original bed, but so as to leave a white face, if possible. The marble in the same vein will be partly white and partly colored. The so-called fancy marbles all come out of the same quarry—red, white, black and blue—and sometimes even out of the same piece. The whole plant of these quarries is very fine. The Rutland marble is easily cut into fine lines and ornamental figures. On the other hand, Georgia marble is hard to cut, and unless great care is used large crystals will break out in cutting.

The Building Committee advised the use of granite, but the architects desired to use marble protected, which would be more beautiful and susceptible of elegant ornamentation, and would last a long time. But Mr. Wade said he wanted a building that would last five hundred years, therefore the idea of marble had to be abandoned.

Many samples of granite were sent to the architects. Granite is refractory and has to be tooled by hard and patient labor. Pneumatic tools have been invented for undercutting, but plain surfaces are generally worked by hand. Granite does not lend itself to fine ornamental lines and its gray color prevents the best effects of light and shadow.

Of course, it was necessary to change the ornamental design of the building to suit the change in material and arrange for heavier blocks in the walls. Marble can be used as veneering. It can be sawed as thin as five-eighths of an inch, but granite must be in blocks.

The granite found in the Barre Quarries occurs in layers separated by parallel seams through which water trickles. The stone next the seam is consequently saturated, and is called the sap. The sap is rejected in building, requiring a dressing off of the blocks of two or three inches from each bed. Usually granite blocks are split apart, though some sawing is done with chilled shot. At these quarries rotating disks are used to dress granite surfaces. The stone is first roughly pointed by hand and then run under the machine, which dresses off the surface to an absolute plane. This result is seldom obtained in hand work. In hand dressing a "number ten cut" (which means ten bits in ⅝ of an inch) is about the best, but more

depends on the skill of the laborer than upon the number of bits to the inch.

Of all the granites, the North Jay seems to have the lightest color. Grant's tomb and the new Bowling Green, New York, are built of this. It is, however, rather porous and soft and occasionally discolored by iron. A few defective blocks may spoil the effect of an entire building. Westerly granite is the darkest of all. The Concord granite is used in the Congressional Library Building at Washington. It contains some particles of magnesia. The Troy, N. H., granite is light and sound and of good quality. It forms the steps of the Congressional Library. The Halliwell granite was used in building the State Capitol at Albany. Barre has the most prolific quarries in America, but the product is liable to have iron in it, at least in the sap. Small specks of iron, hardly detected in the first instance, will later dissolve and streak the whole surface. However, it has been used for twenty-five years, and some monuments built of it are still as good as new. Many fine specimens of this granite may be seen in Lake View Cemetery.

The Halliwell granite is the best and most expensive, and is largely used for monumental work. It is homogeneous, all sections presenting the same appearance in whatever direction they are taken.

It was finally decided to use either the Troy or the Barre granite in the Memorial Chapel.

In conclusion, Mr. Hubbell stated that although Mr. Wade was recommended by friends to go to New York, or even to Europe, to select his architect, he nevertheless decided that this building should be designed and constructed by Cleveland architects.

The speaker exhibited various samples of marble and granite, illustrating the effect of shade and color. Many of these were very handsome and were examined with great interest. There was one sample of white Italian marble which had been exposed to the Cleveland climate for years, till its surface was black, and it had so far disintegrated that it could be crumbled between the thumb and finger.

A discussion ensued in which Messrs. Barnum, Hopkinson, Boalt, Searles and Benes participated.

On motion of Mr. Hopkinson, a vote of thanks was tendered Mr. Hubbell for his interesting and instructive address.

At 10 o'clock the Club adjourned and luncheon was served.

Boston Society of Civil Engineers.

Boston, June 15, 1898.—A regular meeting of the Boston Society of Civil Engineers was held in Lorimer Hall, Tremont Temple, at 8 o'clock p.m.; President Howard A. Carson in the chair; fifty-two members and visitors present.

The record of the last meeting was read and approved.

Messrs. John A. Holmes and Eugene C. Hultman were elected members of the Society.

The Secretary read a letter from Mr. Clemens Herschel, member of the Society, offering to present to the Society a piece of ancient Roman pipe on condition that the Society would undertake to properly mount it and preserve it. On motion of Professor Allen, it was voted: That the Secretary be authorized to inform Mr. Herschel that it would give the Society

great pleasure to receive the section of ancient Roman pipe, and the Society will mount it, place it in the library and adopt reasonable precautions for its safety.

The President announced that the 3d of July will be the fiftieth anniversary of the organization of the Society, and suggested that the event should be observed in a fitting manner. The Board of Government had considered the matter, and inasmuch as the exact anniversary occurred on Sunday, it recommended that the celebration be held early in October, next, and that it take the form of a social gathering, at which an historical address should be delivered, and other appropriate exercises held. On motion of Mr. G. A. Kimball, it was voted: That the Society approve the measure and method of celebrating the semi-centennial anniversary of the organization of the Society, as outlined by the President, and that the arrangement of the details of said celebration be referred to the Board of Government with full powers.

Mr. A. U. Jaastad, of Boston, was then introduced, and read a paper entitled, "Modern Steam Plants for Electric Railways." At the conclusion of the reading of the paper the thanks of the Society were voted to Mr. Jaastad for his interesting paper.

Mr. Gilbert Hodges followed with a paper entitled, "Story of the Street Railway."

Adjourned.

S. E. Tinkham, *Secretary.*

Association of Engineering Societies.

Vol. XXI. AUGUST, 1898. No. 2.

PROCEEDINGS.

Civil Engineers' Club of Cleveland.

Cleveland, August 9, 1898.—The regular meeting was called to order at 8 o'clock by President Osborn. Present, fifteen members and five visitors. The minutes of the last meeting were read and approved.

The Secretary reported for the Executive Board a balance of over $140 in the Library Fund, and invited suggestions as to new books suitable to be purchased for the library.

There being no other business, Mr. Lehman B. Hoit, member of the Club, then read a paper on "Test Meters for Steam Boilers," and also gave some notes upon "Steam Accumulators" and exhibited a working model of a water meter.

The topics were discussed by Messrs. Palmer, Roberts, Porter, Herman and others.

A social hour followed adjournment, and refreshments were served.

Wm. H. Searles, *Secretary.*

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N. DAK.
S. DAK.
NEBR.
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Association

of

Engineering Societies.

Vol. XXI. SEPTEMBER, 1898. No. 3.

PROCEEDINGS.

Technical Society of the Pacific Coast.

Regular Meeting, August 6, 1898.—An excursion to Mt. Tamalpais and an informal meeting there having been planned by the directors, the members of the Society, accompanied by their ladies, met at the ferry station and crossed the bay on the 9.30 a.m. Sausalito steamer. The ascent of the train to the summit of the mountain was enjoyed by all.

After luncheon at the Mountain Tavern, the meeting was called to order by Vice-President Percy, whereupon Mr. W. H. Hammon and Mr. McAdie, of the United States Weather Bureau, addressed the members on the subject of scientific kite flying, explaining in detail the principles and the construction of a modern kite and the results that may be achieved through their use in meteorological science. A discussion followed, carried on by Colonel Mendell, Mr. John Richards and others.

A rising vote was tendered to the authors for their interesting paper.

The meeting then adjourned, and the party returned to San Francisco on the 4.20 p.m. train.

Otto von Geldern, *Secretary.*

Regular Meeting, September 2, 1898.—Called to order at 8.30 p.m. by President Molera.

The minutes of the last two previous meetings were read and approved.

Mr. G. W. Percy read a paper, entitled "Roman Construction," which was discussed by many members and visiting architects.

Adjourned.

Otto von Geldern, *Secretary.*

Engineers' Club of St. Louis.

475th Meeting, September 21, 1898.—The meeting was held at 1600 Lucas Place, at 8 p.m., with President Bryan in the chair. Nineteen members and seven visitors were present.

The President addressed the Club, stating that as the meeting was in memory of the late Colonel Flad, all routine business would be dispensed with. He stated that the engineer seldom accumulates wealth, and that communities seldom erect monuments to his memory, but that his monu-

ments consist in the structures which are erected by him and in the esteem of his fellow-engineers. He referred to the close connection of Colonel Flad with the Engineers' Club of St. Louis, and introduced Mr. Robert Moore as the principal speaker of the evening.

Mr. Moore began with a biographical sketch of Colonel Flad, stating that he was born in the Grand Duchy of Baden in 1824, was educated at the University of Munich, entered the government engineering corps, and came to this country in 1849 on account of his participation in the parliamentary war of 1848. He was engaged in the construction of the New York and Erie Railroad, the Ohio and Mississippi Railroad and the Iron Mountain Railroad. When the war broke out he was appointed captain and afterwards colonel of engineers. After the war he returned to St. Louis, and was a member of the Board of Water Commissioners until 1875. He was also principal assistant engineer during the construction of the Eads Bridge. He was president of the Engineers' Club of St. Louis for twelve consecutive years, from 1878 to 1890. He was president of the Board of Public Improvements from 1876 to 1890, and a member of the Mississippi River Commission from 1890 until his death in 1898. The distinguishing characteristics of Colonel Flad were his wonderful fertility of invention and his high standard of honesty.

The Club was then addressed by Dr. C. M. Woodward, Mr. Julius Pitzman, Prof. J. B. Johnson, Mr. B. H. Colby and Mr. Albert Borden, each of whom treated of some event in the life of Colonel Flad or some phase of his character.

The Club then adjourned to the library, where lunch was served.

RICHARD MCCULLOCH, *Secretary.*

Civil Engineers' Club of Cleveland.

CLEVELAND, SEPTEMBER 13, 1898.—The regular monthly meeting was held in Case Library, September 13, at 8 P.M. Both presiding officers being absent, Mr. W. R. Warner was chosen President *pro tem.* Present, twenty-two members and five visitors.

The minutes of the last meeting were read and approved. There was no report from the Executive Board, no session having been held for lack of quorum.

Mr. St. John reported that the Program Committee had provided for all coming meetings this year, but gave no particulars.

The proposed amendment to the Constitution, changing the name of the Club, was then taken up and discussed. Remarks were made by Messrs. Hyde, Miller, Oldham, Baker, Porter, Searles, Mordecai and Prof. Benjamin. The question being put on Mr. Swasey's amendment, viz., that this Club be called "The Cleveland Society of Civil Engineers," was lost by a large majority. The question recurring to the original proposition as signed by the petitioners, viz., "The name of this Association shall be 'The Cleveland Society of Engineers,'" was discussed by Messrs. Coffin, Mordecai, Palmer, W. B. Cowles, Hyde, Baker and St. John. Mr. St. John, seconded by Mr. Skeels, moved to amend by substituting the title "The Cleveland Technical Society." This was put to question and lost.

Mr. Mordecai moved the postponement of further discussion of the main question to the next regular meeting. Carried.

Mr. J. P. Coffin then read a paper on "Some Points of Interest Gathered from an Inspection of the Machinery of Vessels on the Great Lakes, Together with a Synopsis of the Rules Compiled by the Great Lakes Register for Future Construction, and the Reasons for the Same," which was listened to with great attention. The paper reported upon the prevailing types of boilers, engines, pumps and other machinery now afloat on the Great Lakes, as ascertained from a critical survey of over 1300 vessels; it mentioned certain defects in design and proportion, and described the rules adopted to govern future construction. The subject was discussed by Messrs. Oldham and Miller, and at 10 o'clock the Club adjourned and refreshments were served.

WM. H. SEARLES, *Secretary.*

Detroit Engineering Society.

THE regular monthly meeting was held at the Hotel Ste. Claire, Friday evening, September 23; Vice-President W. J. Keep presiding, with twenty-four members and seven visitors present.

The Executive Committee reporting favorably upon the following applications, the candidates were elected to membership: L. C. Sabin, U. S. Asst. Eng., Port Huron, non-resident; S. H. Woodard, Asst. Eng., Deep Waterways Commission, resident; H. S. Bissell, Supt. Page Wire Fence Co., Walkerville, Ont., resident.

A communication from the American Society of Civil Engineers, containing resolutions of thanks for assistance in connection with the Thirtieth Annual Convention, was read and placed on file.

Messrs. Walter F. Beyer and John R. Allen were proposed for membership and referred to the Executive Committee.

The Secretary presented his resignation, to take effect October 1, 1898, which was accepted; and upon the nomination of the Executive Committee, Mr. Henry Goldmark was confirmed as his successor.

The paper of the evening, "Sanitary Engineering in Detroit," was presented by Mr. A. B. Raymond, Sanitary Engineer to the Board of Health, and was discussed by Messrs. Dow, Goldmark, Keep, Williams, Woodard, Molitor and the author.

Adjourned.

GARDNER S. WILLIAMS, *Secretary.*

MEETING of the Executive Committee, held at 57 E. Hancock avenue, September 22, 1898. Present, Messrs. Keep, Dow, Russel, Smith, Hinchman and Williams.

Candidates for membership proposed at the last meeting were unanimously endorsed.

The Secretary announced his resignation, and Mr. Henry Goldmark was unanimously nominated to succeed him.

Bills of Spitzley Bros., for blackboard, amounting to $6.25, and of Richmond, Backer & Co., for printing, etc., amounting to $8.45, were approved and ordered paid.

GARDNER S. WILLIAMS, *Secretary.*

Association of Engineering Societies.

Vol. XXI. OCTOBER, 1898. No. 4.

PROCEEDINGS.

Engineers' Club of St. Louis.

476TH MEETING, OCTOBER 5, 1898.—The meeting was held at 1600 Lucas Place, at 8 P.M., with President Bryan in the chair. Sixteen members and two visitors were present. The minutes of the 474th and the 475th regular meetings and the 261st and 262d meetings of the Executive Committee were read and approved.

The Secretary announced that he had received applications for membership from Messrs. Denney W. Roper, Victor Henry Poss, Charles W. Chassaing, Alfred Boyd and Samuel Trepp.

The applications for membership of Messrs. Albert B. Hazzard and Lovell Henry Carr having been approved by the Executive Committee, these gentlemen were balloted for and elected members of the Club.

Prof. J. H. Kinealy moved that the Secretary address letters of thanks to the Wiggins Ferry Company and to Mr. Lemon Parker for courtesies extended to the Club during the summer. This motion was unanimously carried.

A letter was then read from Mr. Charles L. Bouton, who had been appointed a delegate from the Engineers' Club of St. Louis to the Fiftieth Anniversary Celebration of the Society of Civil Engineers of France.

The President stated that the Missouri Historical Society had invited the Club to participate in the arrangements for the celebration of the Louisiana Purchase.

The discussion of the smoke abatement movement in St. Louis was then taken up. Mr. Eugene McQuillan, the attorney of the Citizens' Smoke Abatement Association, addressed the Club in regard to the legal questions involved. He stated that an ordinance had been passed by the Municipal Assembly several years ago which prescribed a punishment for the emission of dense, black smoke. Several convictions had been secured under this ordinance and the smoke nuisance had been largely abated, until on an appeal case the Supreme Court of Missouri decided that the Municipal Assembly had exceeded its rights under the city charter in passing the ordinance. Mr. McQuillan stated that a new ordinance was in course of preparation and is soon to be introduced in the Municipal Assembly.

Remarks on the subject of Smoke Abatement were then made by Col. E. D. Meier, Messrs. Robert E. McMath, Robert Moore and M. L. Holman.

There being no further business, the Club adjourned to the library.

Richard McCulloch, *Secretary.*

477th Meeting, October 19, 1898.—The meeting was held at 1600 Lucas Place, at 8 p.m., with President Bryan in the chair. Twenty-six members and nine visitors were present. The minutes of the 476th regular meeting and the 263d meeting of the Executive Committee were read and approved.

The Executive Committee having reported favorably upon the applications for membership of Messrs. Denney W. Roper, Victor H. Poss, Alfred Boyd, Charles W. Chassaing and Samuel Trepp, these gentlemen were balloted for and elected members of the Club.

Mr. S. Bent Russell moved that the members of the Board of Managers of the Association of Engineering Societies representing the Engineers' Club of St. Louis be instructed to bring before the Board of Managers the question of publishing annually in the Journal a list of all the members of all the Clubs belonging to the Association. After some discussion, this motion was carried.

The paper of the evening, by Mr. B. H. Colby, was then read. It was entitled "Repairs to the Mill Creek Sewer." A sketch of the history of this sewer was given. Its section is twenty by fifteen feet and its present length is about 25,000 feet. The present dry weather flow is about 40,000,000 gallons. It was begun in 1860 and has been built by piecemeal. The sewer was originally built on a timber bottom and the weight of the side walls has forced up the timber under the center of the sewer. The timber is now being replaced by a concrete inverted arch and the methods employed to effect these repairs were described. A large number of lantern slides were used to illustrate the subject.

The paper was discussed by Messrs. Moore, Pitzman, Ockerson and Holman.

There being no further business, the meeting adjourned.

Richard McCulloch, *Secretary.*

Boston Society of Civil Engineers.

Boston, September 21, 1898.—A regular meeting of the Boston Society of Civil Engineers was held in Chipman Hall, Tremont Temple, at 8.15 o'clock p.m.; President Howard A. Carson in the chair; ninety-two members and visitors present.

The record of the last meeting was read and approved.

Messrs. Frank S. Bailey, Edward D. Sabine and Gilbert S. Vickery were elected members of the Society.

On motion of Professor Allen, the thanks of the Society were voted to the New England Gas and Coke Company, to Col. S. M. Mansfield, Engineer Corps, U. S. A., and to the Portland Stone Ware Company, for courtesies extended to the members of the Society on the occasion of the several excursions made during the past summer. The thanks of the Society were also voted to the American Street Railway Association for the compli-

mentary tickets admitting our members to the Association's exhibition recently held in Boston.

The Secretary read a letter from the Secretary of the Society for the Promotion of Engineering Education, conveying a vote of thanks from that Society for the courtesies shown its members by this Society in arranging excursions to points of engineering interest during the recent meeting in Boston.

The President announced that the semi-centennial celebration of the Society would take place early in November.

The literary exercises of the evening took the form of a talk by President Howard A. Carson on the proposed East Boston tunnel, illustrated by lantern views. Mr. Carson briefly reviewed the various methods of submarine tunneling, and spoke particularly of the method of placing tubes in dredged trenches as used in the tunnel under Shirley Gut for the Metropolitan Sewerage System. In the studies for the East Boston tunnel this method has been considered, but as yet no plan had been adopted. Mr. Carson also discussed the various routes which had been proposed and the plans for connecting the Boston end with the subway. Adjourned.

S. E. Tinkham, *Secretary.*

Boston, October 19, 1898.—A regular meeting of the Boston Society of Civil Engineers was held in Chipman Hall, Tremont Temple, at 7.50 o'clock P.M.; President Howard A. Carson in the chair; sixty-five members and visitors present.

The record of the last meeting was read and approved.

Messrs. John B. Blood, Harry G. Botsford and Homer R. Stanford were elected members of the Society.

Prof. Ira N. Hollis occupied the evening with an informal talk on "The Engineering Features of the Spanish War." Adjourned.

S. E. Tinkham, *Secretary.*

Civil Engineers' Club of Cleveland.

Cleveland, October 11, 1898.—The regular monthly meeting was held in Case Library at 8 P.M. President Osborn in the chair. Present, sixteen members and four visitors. The minutes of the last meeting were read and approved. There was no report from the Executive Board, no session having been held owing to the lack of a quorum.

A letter was read from Mr. John C. Trautwine, Jr., Secretary, addressed to the Club, urging the securing of advertisements for the Journal. On motion of Mr. Mordecai, the letter was referred to the Executive Board for action.

The discussion upon the proposed amendment to the constitution was resumed. Remarks were made by Messrs. Mordecai, Hyde, Gobeille, Oldham, Parmley and Dr. Langley. Mr. Parmley moved as an amendment, to strike out "The Cleveland Society of Engineers" and insert "The Cleveland Engineering Society." This was seconded by Dr. Langley and discussed by Messrs. Oldham and Hoit. The amendment was put to vote and received, ayes 9, noes 4, not voting 3; total 16. The amendment was declared adopted and the petition as amended was ordered to letter ballot.

Mr. Arthur A. Skeels, member of the Club, presented some "Notes and Observations on a Recent Trip Through Mexico." His description of the numerous cities which he visited was illustrated by a large number of fine photographs taken by himself. These views represented street scenes, cathedrals, towers, aqueducts, waterfalls, volcanoes, plantations, etc. He described Monterey as being a most ancient and foreign looking city, with houses of adobe. Its water supply is taken from local wells and its sanitation is exceedingly bad. It, however, enjoys electric lights, and street cars hauled by mules, tandem.

The Castle of Chapultepec, a very beautiful and imposing structure, is the official residence of President Diaz. At Tlaxcala is seen the tower of a church built by Cortez, the oldest in Mexico.

Some of the natural scenery is Swiss-like in its grandeur and beauty, particularly in the vicinity of Orizaba.

At Queretaro there is a long stone viaduct, of considerable height carrying the water supply to the city, where beautiful fountains are constantly playing.

Guadalajara is the most beautiful town in Mexico; the theater and church are magnificent edifices and not far away are the Falls of Juanacatlan, the largest waterfalls in Mexico. These falls are utilized for power and the production of electric lights which are used in the city.

The lecture was highly enjoyed by those present. The Club then adjourned for luncheon.

Wm. H. Searles, *Secretary.*

Louisiana Engineering Society.

New Orleans, October 10, 1898.—The regular monthly meeting of the Louisiana Engineering Society was called to order this date at 8.10 p.m. by President Sidney F. Lewis, with fourteen members and two guests present. The minutes of the last meeting were read and approved; and, for the information of the members, the minutes of the meeting of the Board of Direction were also read.

The report of the Auditing Committee, submitting the statements of the Secretary and Treasurer which they had audited, was read and ordered filed. The Committee on an Excursion reported progress.

There being no other business, technical exercises were declared in order, and Mr. Coleman read a short paper seeking to open discussion on either one of four subjects,—viz., Bank Protection, Drainage, Sewerage, or the proposed construction and track rearrangement on Canal street, of which all the plans were submitted. Mr. Bell fully explained these plans, and read his report to the City Council on the subject. A discussion ensued which was participated in by Messrs. Harrod, Fox, Theard, Lombard, Tutwiler and Grandjean.

Upon motion by Mr. Fox, Mr. Coleman was tendered the thanks of the Society for his paper.

There being no further business, the meeting was adjourned at 9.40 p.m.

J. F. Coleman, *Secretary.*

Engineers' Society of Western New York.

At the September meeting of the Engineers' Society of Western New York Mr. H. L. Noyes read a very interesting paper on "The History of Bridges." At the October meeting Mr. T. Guilford Smith favored us with a paper on "Important Works in Egypt," which was extensively discussed.

From October 18 to 22, inclusive, we had the pleasure of entertaining the American Institute of Mining Engineers at their 75th meeting, held in Buffalo. Souvenir badges and descriptive pamphlets of information were distributed. A harbor excursion was given the visitors, as well as a reception at the Ellicott Club. At the introductory meeting the public library was open from top to bottom, thus offering the Academy of Natural Sciences, the Historical Society Rooms and Fine Arts Rooms and the library proper open to inspection, the officers of the several organizations being present to welcome the Institute members. One day was set apart for visiting the various manufacturing places of interest. The last day was spent at Niagara Falls. The local committee from our Society appointed to welcome the guests was composed of the following: W. C. Johnson, T. Guilford Smith, E. B. Guthrie, H. J. March, Carl Meyer, E. C. Lufkin, Geo. S. Hubbell, H. L. Noyes, Pemberton Smith and Mr. Shattuck. They all spent a great deal of time in perfecting arrangements, which were heartily appreciated by the Institute.

H. J. March, *Secretary.*

Technical Society of the Pacific Coast.

Regular Meeting, October 7, 1898.—Called to order at 8.30 p.m. by President Molera. The minutes of the last regular meeting were read and approved.

A letter was read from the Secretary of the Association of Engineering Societies, communicating a decision of the Board of Managers to allow the Societies a commission of 90 per cent. on any advertisement secured for the Journal, and suggesting the appointment of a committee from the Technical Society for the purpose of taking this matter under consideration and pushing it vigorously to a successful issue. Upon motion it was ordered that the Board of Directors be instructed to appoint a committee of three to investigate the possibility of securing suitable advertisements for the Journal, and to report thereon at an early convenience.

Mr. H. M. Kebby read a paper descriptive of an instrument called the "Econometer," a mechanical contrivance for weighing the percentage of carbonic acid developed during combustion. The paper was discussed at length, after which the meeting adjourned.

Otto von Geldern, *Secretary.*

ASSOCIATION
OF
ENGINEERING SOCIETIES.

VOL. XXI. NOVEMBER, 1898. No. 5.

PROCEEDINGS.

Engineers' Club of St. Louis.

478TH MEETING, NOVEMBER 2, 1898.—The meeting was held at 1600 Lucas Place at 8 P.M., with President Bryan in the chair. Twenty-seven members and four visitors were present. The minutes of the 477th regular meeting and the 264th meeting of the Executive Committee were read and approved.

The Secretary announced that he had received an application for membership from Mr. Mark Bary, assistant in the office of Bryan & Humphrey.

Capt. F. H. Macklind gave an address upon "Roads and Roadways." He pointed out the necessity of good roads to our present civilization and showed how city streets had developed from country roads. A brief history was given of the street making and paving which had been done in St. Louis. The value of various pavements from different standpoints was discussed, and the paper closed by giving the methods used and the cost of cleaning the streets in different cities. A discussion of this subject followed, participated in by Messrs. Bouton and McCulloch.

Prof. Kinealy then exhibited a machine for boring triangular, square, pentagonal, hexagonal and octagonal holes. The machine can be used in connection with any drill press and bores the hole at one operation in about twice the time taken to bore a round hole. The inventor of the machine was introduced to the club and explained the manner of operating the drill.

An informal discussion followed, after which the Club adjourned.

RICHARD MCCULLOCH, *Secretary.*

479TH MEETING, NOVEMBER 16, 1898.—Meeting was called to order at 8.15 P.M.; President Bryan in the chair. Thirty-two members and thirteen visitors were present. On explanation by the chair that at this meeting it has always been customary to appoint a committee on nominations for officers for the ensuing year, Mr. Colby moved that a nominating committee of five be appointed by the chair. The motion was seconded and unanimously adopted. The chair announced the receipt of a report of the Massachusetts Board of Health and a report of the Missouri Geological Survey.

Prof. J. B. Johnson then presented his paper entitled "The Engineer as the Guardian of Public Health." The paper was brought out mainly by

the recent development of the new theory of infectious diseases, whereby the engineering field has been greatly widened. The paper dealt with the various means by which the injurious bacteria found their way into the human system, and stated that it is very largely the scope of the engineer to supply means of prevention of such infection, such as the proper building and cleaning of streets, removal of sewerage and the supplying of pure drinking water. Some interesting statistics were given showing the decrease in the death rate due to typhoid fever, which was brought about by changes in source of supply and by filtration, and comparisons were made with German statistics, in which country the filtration of water supplies is almost universal. The universal adoption of sand filters in this country was urged as necessary to the preservation of public health, but notwithstanding the great progress in Germany but little advance has been made here. It is unquestionably true that municipalities can be held liable for the results of the furnishing of impure water.

As engineers understand causes of disease as well as the methods of prevention, it is their duty to form and lead public opinion, in providing safeguards to preserve the public health.

The writer traced some of the unsanitary arrangements of our residences and criticised slightly some defects of our sewer system. As we are provided with surface water from the Mississippi River, itself a great natural sewer, and as we are soon to have the sewage from a great city turned into this river, it will be an absolute necessity to provide a filtration plant for our water supply. The paper concluded with a brief statement of the duties of engineers in the preservation of public health and happiness.

The discussion, participated in by Messrs. Colby, Moore, Johnson and Dr. Ravold, was very interesting.

The President announced as the Committee on Nominations Messrs. Ockerson, Russell, Holman, Herman and Layman.

On motion the meeting adjourned.

E. R. Fish, *Secretary pro tem.*

Detroit Engineering Society.

The 33d Regular Meeting was held at the Hotel Ste. Claire, October 21, 8 p.m.; Mr. W. J. Keep, First Vice-President, presiding. There were twenty members and guests present. Mr. J. R. Allen, University of Michigan, Ann Arbor, and Mr. Walter F. Beyer, U. S. Engineer Office, Detroit, were elected to membership.

On motion of Mr. Pope, the President was instructed to appoint a committee of three to draw up suitable resolutions commemorative of the valuable work done by Mr. G. S. Williams, late Secretary of the Society, in forwarding its interests and advancing its prosperity. The motion was discussed by Prof. Greene and Messrs. Dow, Mattson and W. S. Russel. Messrs. Greene, Wisner and W. S. Russel were appointed as members of the committee.

The paper of the evening, "Coal-Handling Machinery," was then read by the author, Mr. C. W. Russell.

It was discussed by Messrs. Dow and C. W. Russell.

Adjourned.

Meeting of Executive Committee, held October 21, 1898.—Present: Messrs. Keep, Hinchman, Pope and the Secretary.

The bill of G. S. Williams, Secretary, for stationery and postage was approved and ordered paid.

On motion of Mr. Pope, the Secretary was instructed to arrange for the printing of a new edition of the Constitution and list of members.

The resignations of Messrs. H. R. King and I. G. Sowter were accepted.

Mr. J. A. Mayers was proposed as a member by Mr. J. F. Lewis.

Adjourned.

The 34th Regular Meeting of the Society was held at the Hotel Ste. Claire, November 25, 1898, 8 p.m.; Mr. Geo. Y. Wisner, President, in the chair. There were thirty-five members and guests present.

On ballot, Mr. J. A. Mayers, of Detroit, was elected a member of the Society.

Prof. Chas. E. Greene, as chairman of the committee appointed at the last meeting, presented resolutions expressing the appreciation of the Society of the work done by Mr. G. S. Williams as Secretary. On motion, it was voted that the resolutions be printed in the Journal and a properly engrossed copy be sent to Mr. Williams.

The paper of the evening, "Experiences in the Engine Room of the U. S. S. Yosemite," was then read by the author, Mr. T. H. Hinchman, Jr. It was discussed by Messrs. Campau, Dow, Mattson and the author.

Adjourned.

Meeting of the Executive Committee, held November 25, 1898.—Present: Messrs. Wisner, Pope, Dow, Keep, Hinchman and the Secretary.

The application of Mr. J. A. Mayers for membership was approved and a ballot ordered to be taken at the next meeting of the Society.

Mr. Chas. O. Cook, a member of the Society, was, on his request, granted a transfer to the Cleveland Engineers' Club.

A letter was read from Mr. E. R. Stoddard, Secretary of a Joint Committee of the several Associations of Detroit Stationary Engineers, inviting the Society to co-operate in drafting a new ordinance with regard to the inspection of steam boilers in the city of Detroit. The judgment of the members was adverse to the proposed action, and the Secretary was instructed to inform the writer of the communication to that effect.

Adjourned.

Henry Goldmark, *Secretary.*

Resolutions adopted by the Detroit Engineering Society, November 25, 1898, appreciative of the work done by Mr. G. S. Williams as Secretary of the Society:

The members of the Detroit Engineering Society regret that the appointment of Mr. Gardner S. Williams to the Chair of Experimental Hydraulics at Cornell University has obliged him to resign the office of Secretary and to give up active participation in the affairs of the Society.

Its organization was due, in a very large measure, to Mr. Williams' earnest efforts, and his careful attention to all details has greatly furthered

its development. The Society desires to put on record its sincere appreciation of the deep interest which he has always shown in its work.

As engineer to the Detroit Water Board, Mr. Williams has proved not only that he is a skillful civil and hydraulic engineer, but also that he is remarkably well fitted to carry on research and experiments that require great care and accuracy. Results already obtained by him promise to throw much light on obscure hydraulic phenomena.

While the Society regrets to part with Mr. Williams, it rejoices that the academic position to which he has been called will open to him such a large and congenial field for investigation; and it anticipates the satisfaction of sharing with the profession at large in the results of hydraulic experiments conducted on a large scale with far better facilities than can often be commanded.

Signed,
Chas. E. Greene,
Geo. Y. Wisner,
Walter S. Russel,
Committee.

Louisiana Engineering Society.

New Orleans, November 5, 1898.—Despite the threatened inclemency of the weather some forty-two members and two hundred and fifty guests, including many ladies, met this day at noon, at the depot of the Spanish Fort Railroad, for the first "outing" of this Society. The party, after visiting the work being prosecuted near by on the drainage system, boarded a chartered train and visited other parts of the drainage system in course of construction, stopping at Pumping Stations 2 and 7, No. 2 being at Broad and St. Louis streets and No. 7 at the intersection of the Spanish Fort Railroad with the New Orleans and Western Railroad.

The Central Power Station was the next stopping point. The purpose of the system and the manner in which it is being carried out were explained here in a short address by Mr. Thos. L. Raymond, after which a lunch was partaken of. The party then proceeded to the Jourdan Avenue Pumping Station, which was in operation. This is the outermost station of the system.

After leaving this point the train carried us to Port Chalmette, where the terminal facilities were inspected, after which the entire party returned to the city at 5.45 p.m., having thoroughly enjoyed the outing.

J. F. Coleman, *Secretary.*

New Orleans, November 14, 1898.—The regular monthly meeting of the Louisiana Engineering Society was called to order this date at 8.10 p.m., at the rooms of the Society, by President Sidney F. Lewis, with twenty-two members and three guests present. The minutes of the last meeting were read and, upon motion, approved. For the information of the members, the minutes of the Board of Direction were also read. The Auditing Committee reported by transmitting the statements of the Treasurer and of the Secretary, which they had audited and found correct. These statements, which showed a balance in hand of $371.28, were ordered filed. The Outing Committee stated that a report on the outing would be submitted as soon as all the bills were in hand, which would probably be

at the December meeting. Incidentally, the President requested all members who proposed bringing in applications from their brother professionals for membership to try and have them in the Secretary's hands by December 1, so that the letter ballot could be issued at such time as would perfect membership by January 1, 1899.

Technical exercises being next in order, Mr. A. F. Woolley, Jr., read a paper on "The Rectification of Red and Atchafalaya Rivers," which was an exposition of all the plans that have been considered for that end and a statement of the work that has been done. It was listened to with interest, and discussed by Messrs. Harrod, Fox, Raymond and Coleman.

Upon motion, the thanks of the Society were tendered Mr. Woolley for his paper. Announcement was made that at the December meeting, on the 12th of that month, the paper would be by Mr. A. C. Bell, on "The History of Street Pavements in New Orleans."

Upon motion, the thanks of the Society were tendered to the National Contracting Company and to the New Orleans and Western Railroad Company for courtesies extended by them on the occasion of the outing.

There being no further business, the meeting was adjourned.

J. F. COLEMAN, *Secretary.*

Civil Engineers' Society of St. Paul.

ST. PAUL, MINN., NOVEMBER 23, 1898.—The members of the Minneapolis Engineers' Club and others to the number of twenty-one, on invitation of the Civil Engineers' Society of St. Paul, met eleven of our members at 3 P.M. on the Selby Avenue Hill to inspect the working of the car-raising device under the direction of Mr. David Curtin. At 4.30 P.M. President Estabrook called the party to order in Parlor B, Hotel Windsor, where Mr. Curtin explained the drawings and distributed them for examination. At 5.30 the members of our Society withdrew to an adjoining room long enough to elect Mr. C. A. Winslow Treasurer *pro tem.* All were then assembled in Parlor B to listen to remarks by Prof. Hoag, Mr. Crosby and others. Supper was announced at 6 P.M. This finished, the company returned to the parlor to smoke, resolve and pass an indefinite time socially. Mr. Crosby introduced the following resolution, which was passed:

WHEREAS, we have this day examined the Bronsdon counterbalance on the Selby Avenue Hill, which has been operated during the past three months for a distance of 1000 feet; 500 feet on a 16 per cent. grade, thence about 200 feet on a curve and continuing to foot of lighter grade.

RESOLVED, That in our opinion the installation of this device is thorough and durable in character. The iron and steel work seems well proportioned with abundance of material in the various parts and the workmanship is apparently good.

RESOLVED further, That the Twin City Rapid Transit Company is to be commended for its effort to provide the public safe passage over this formidable ascent by means of a device which gives every indication of continued success.

Mr. Wilson, seconded by Mr. Howe, offered the following:

RESOLVED, That the members of the Civil Engineers' Society of St. Paul and the Minneapolis Engineers' Club hereby extend their thanks to the officers of the Twin City Rapid Transit Company for the opportunity of

examining the Bronsdon counterweight device in operation on the Selby Avenue Hill, and for the special facilities afforded for that purpose.

President Cappelen, on behalf of the Minneapolis Club, closed the business of the evening by inviting the St. Paul Society to visit the Beet Sugar Plant at St. Louis Park the coming month.

C. L. ANNAN, *Secretary.*

Technical Society of the Pacific Coast.

REGULAR MEETING, NOVEMBER 4, 1898.—Called to order at 8.30 P.M. by Professor Chas. D. Marx. The minutes of the last regular meeting were read and approved.

Mr. D. C. Henny read a paper, entitled "Wooden Stave Pipe in Comparison with Riveted Steel Pipe, with particular reference to the proposed Coolgardie Pipe Line." A discussion of the same subject was submitted by Mr. C. E. Grunsky and read by the Secretary. A long and interesting discussion then followed, in which many of the members present participated. Particular reference was made to the velocities obtained by the use of the Chezy and Kutter formulæ, differing opinions being expressed as to the reliability of these aids for pipes of larger diameter. Professor L. M. Hoskins discussed this particular feature, referring to experiments on the flow of water in the six-foot steel and wood pipe line of the Pioneer Electric Power Company, at Ogden, Utah, made by Professors Marx, Wing and Hoskins, in August, 1897. Upon motion a vote of thanks was passed for the author of the interesting paper.

Meeting adjourned.

OTTO VON GELDERN, *Secretary.*

Montana Society of Engineers.

THE regular monthly meeting of the Society was held in its rooms in Helena, Montana, on October 8. Meeting called to order at 8 P.M.; Vice-President F. J. Smith in the chair.

The minutes of the last meeting were read and approved. The application for membership of Mr. William Braden was favorably considered and the Secretary instructed to send out the usual letter ballots.

Helena was selected as the place for holding the Twelfth Annual Meeting of the Society.

A committee on arrangements consisting of J. S. Keerl, of Helena, Elliott H. Wilson, of Butte, and John C. Patterson, of Great Falls, was appointed to arrange the program. Paul S. A. Bickel, of Helena, Benjamin Bond, of Dillon, and Frank M. Leonard, of Libby, were appointed a committee to nominate officers for the ensuing year. A committee consisting of F. W. Blackford, John Herron and F. L. Sizer, appointed to draft a bill providing for a State Engineer and defining his duties, presented such a bill, which was accepted and the committee requested to again present the bill at the next meeting for discussion.

Votes of thanks were tendered to Messrs. Ellwood Mead, State Engineer of Wyoming, and Charles D. Walcott, director of the U. S. Geological Survey, for recent interesting and instructive lectures before the Society, and to the School Trustees for the use of the assembly room of the Helena High School on said occasions.

A. S. HOVEY, *Secretary.*

Association of Engineering Societies.

Vol. XXI. DECEMBER, 1898. No. 6.

PROCEEDINGS.

Louisiana Engineering Society.

New Orleans, December 12, 1898.—The regular monthly meeting of the Louisiana Engineering Society was called to order this date at 8.05 p.m., by President Lewis, with twenty-seven members and six guests present. The minutes of the last meeting were read and approved.

The report of the Treasurer, which had been approved by the Auditing Committee, was read and referred to the Board of Direction.

There being no other business, technical exercises were declared in order, and an interesting and instructive paper was read by Mr. A. C. Bell on "The History of Street Paving in the City of New Orleans, and Discussion as to the Most Suitable Pavements for Traffic and other Correlative Conditions." At the conclusion of the paper, remarks were made by Mr. Grandjean on the maintenance of street pavements, or rather the lack of it in New Orleans; and Mr. Lombard spoke of the relative merits of gravel pavements here and elsewhere. Mr. Malochee, in discussing that part of Mr. Bell's paper which spoke of the necessity of a testing laboratory as an adjunct to the City Engineer's Office, expressed himself as being of the opinion that it is as great a necessity that the City Engineer's Department should be a permanent one, in which neither the head nor the subordinates could be disturbed by politics. He favored a permanent Board of Public Works, and finally moved that the administration of this Society shall submit a plan for such efforts on the next session of the Legislature, as will attain some such end, and will effect a more stable method of handling the Engineering Departments than now exists. This motion being duly seconded was passed. Mr. Lombard moved that the thanks of the Society be extended to Mr. Bell for his able paper. Carried unanimously.

Adjourned.

J. F. Coleman, *Secretary*.

Civil Engineers' Club of Cleveland.

Cleveland, O., December 13, 1898.—The regular monthly meeting was held in Case Library, December 13, at 8 p.m.; President Osborn in the chair. Present, twenty-one members and four visitors. The minutes of the last regular meeting were read and approved.

The President appointed Messrs. E. C. Cooke and J. W. Beardsley tellers to canvass the ballots received on applications for membership, and, on receiving the tellers' report, he announced that Walter Morrison Allen and Henry Martin Lucas were duly elected active members.

The Executive Board reported the applications of Chas. Olney Cook and Frederick Metcalf for active membership, and recommended them for letter ballot.

On motion of Mr. J. C. Beardsley, seconded by Mr. E. C. Cooke, the following resolutions were adopted:

Resolved, That a committee be appointed to investigate the feasibility of renting quarters for the Club in the new building of the Chamber of Commerce, and to report thereon at the next regular meeting.

Resolved, That the committee above mentioned be directed to confer with the Cleveland Architectural Club, Electric Club and Chemical Society with the view of securing their co-operation in the foregoing project.

The President appointed Messrs. J. C. Beardsley, W. R. Warner and Wm. B. Cowles to serve as such committee.

Mr. Edwin L. Thurston, associate member of the Club, read an instructive paper on "The Nature and History of Patent Rights." He defined the origin and limitation of the rights enjoyed by a holder of letters patent, showing them to be only such as the statute confers, and nothing by virtue of natural right or common law.

He discussed the two theories as to the nature of a patent right, the one regarding it as a monopoly, the other as a contract. The latter view has been generally adopted by the courts and by Congress in this country.

The author described the progress of patent law since the reign of James I., of England, in 1623, down to the present time. The first American patent statute went into effect April 10, 1790. Other patent laws were passed later, but in 1836 all preceding acts were repealed and the present system was inaugurated. A new law went into effect January 1, 1898, giving the patentee some additional advantages, and now more than fifteen bills are under consideration by the two Patent Committees of Congress. The paper closed with an apt quotation from one of the annual reports of the Commissioner of Patents.

An interesting discussion ensued between Messrs. Warner, Beardsley, N. P. Bowler, Palmer and Reed, and the author of the paper. The meeting adjourned at 9.30 and an hour was spent in conversation. Lunch was served.

Wm. H. Searles, *Secretary*.

Technical Society of the Pacific Coast.

Regular Meeting, December 2, 1898.—Called to order at 8.30 p.m. by Vice-President Percy. The minutes of the last regular meeting were read and approved.

A Nominating Committee to select a list of officers for the ensuing year was elected by the members present, as follows:

H. C. Behr, C. E. Grunsky, A. Lietz, Luther Wagoner and A. d'Erlach.

Mr. Marsden Manson, State Commissioner of Highways, delivered a lecture on "Roadway Construction in California," illustrated by stereopticon views of interesting localities and structures. A discussion followed. The

chairman thereupon announced the presence of five distinguished architects, who were called to San Francisco at the instigation of Mrs. Phœbe Hearst in connection with the competition for designs for university buildings at Berkeley. These gentlemen, Messrs. J. M. Hewlett and W. J. Lord, of New York; Professor D. Despradelle and Stephen Codman, of Boston, and E. Bauhain, of Paris, were then introduced to the members, who, after adjournment, repaired in a body to a neighboring café for social intercourse and conversation.

Otto von Geldern, *Secretary.*

Montana Society of Engineers.

The regular monthly meeting of the Society was held in its rooms in Helena, Montana, on November 12, 1898. Meeting called to order at 8 p.m.; Vice-President F. J. Smith in the chair.

The minutes of the last meeting were read and approved.

Messrs. Paul S. A. Bickel and L. S. Griswold were appointed tellers to canvass the votes for membership. The votes were all affirmative and Mr. William Braden was declared elected to membership. The bill providing for the appointment of a State Engineer, and defining his duties, was then read section by section and discussed, after which Mr. O. Jackson, recently from Alaska, addressed the Society upon railway, tramway and other improvements now being made in said country. Owing to a lack of time, the reading of the paper by F. W. Blackford, upon the Butte-Centerville Electric Railway, was postponed until the December meeting.

A. S. Hovey, *Secretary.*

Civil Engineers' Society of St. Paul.

St. Paul, Minn., December 5, 1898.—A regular meeting of the Civil Engineers' Society of St. Paul was held at 8.15 p.m.; President Estabrook in the chair and ten members present. Minutes of previous meeting read and approved. A letter from Secretary Trautwine urging the appointment of a local committee to solicit ads for the Journal of the Association was discussed without action as it was considered that the local circulation was insufficient to warrant local advertisements.

The Secretary was instructed to thank Superintendent I. F. Forbes, of the Great Northern Railway Company, and accept invitation to visit shops at some future time.

A revised membership list was ordered printed.

Mr. Charles A. Forbes was elected to membership.

Mr. Oliver Crosby read a paper on "The Manufacture of U. S. 12" Mortar Carriages."

The American Hoist and Derrick Company, of this city, have been turning out these carriages under his direction at the rate of two per month during the past year. He exhibited test pieces of gun iron, the strength of which must be twice that of ordinary cast iron.

After much experimenting in the mixture of various grades of iron he successfully melts, in a cupola furnace, the necessary twenty tons for one pouring, and moulds the same to pass the most rigid inspection.

C. L. Annan, *Secretary.*

Boston Society of Civil Engineers.

November 11, 1898.—A special meeting of the Boston Society of Civil Engineers was held at the Hotel Vendome, Boston, for the purpose of observing the semi-centennial anniversary of the organization of the Society.

There were present one hundred and seventy members and guests, including ladies.

A reception was held from 7.30 till 8 o'clock, the receiving party consisting of President and Mrs. Howard A. Carson, Vice-President and Mrs. C. Frank Allen and Vice-President and Mrs. Alexis H. French. The following members acting as ushers: Fred. V. Fuller, Henry D. Woods, Frank O. Whitney, Leonard Metcalf and Herbert L. Grew.

Soon after 8 o'clock President Carson called the meeting to order, and requested the Secretary to read so e of the communications which had been received from other engineering societies. In response the Secretary read a brief letter from Mr. Alphonse Fteley, President of the American Society of Civil Engineers, expressing his regrets at his inability to be present and conveying his congratulations upon the event which had brought the members together, and his best wishes for the future welfare of the Boston Society. Letters expressing similar sentiments were also received from the President of the Engineers' Club of St. Louis, from the President of the Civil Engineers' Club of Cleveland and from the President of the Detroit Engineering Society.

A cablegram was also read from the President of the Institution of Civil Engineers (London) offering "hearty congratulations to the Boston Society on their fiftieth anniversary."

A letter was read from the President of the Society of Civil Engineers of France alluding to the recent celebration by that Society of its semi-centennial and to the honor and pleasure it had in receiving a delegate from the Boston Society on that occasion. The letter named Mr. Henry D. Woods as a delegate to represent the Society of Civil Engineers of France at this meeting. The President called upon Mr. Woods, who in a very happy manner extended to the Society the congratulations of the French engineers and gave voice to the fraternal sentiments which unite the engineers of the two countries.

President Howard A. Carson then delivered the opening address and took for his subject "Glimpses of Boston Fifty Years Ago."*

At the conclusion of his address the President introduced Mr. Desmond FitzGerald, a Past-President of the Society, who reviewed its history in a very interesting address, tracing its existence from 1848 to the present time.†

The President congratulated the members upon having present on this occasion one of the founders of the Society, and introduced Mr. Samuel Nott, who took part in the first meeting of the Society, and was its Secretary from March 6, 1849, to August 7, 1874.

Mr. Nott expressed his great pleasure in being able to attend the anniversary exercises and gave a few reminiscences of the early days of the Society.

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*The address will be found on page 263 of this number of the Journal.

†The address will be found on page 268 of this number of the Journal.

At the conclusion of Mr. Nott's remarks the literary portion of the celebration closed.

A collation was then served, after which music and dancing concluded the program.

S. E. TINKHAM, *Secretary.*

NOVEMBER 16, 1898.—A regular meeting of the Boston Society of Civil Engineers was held in Chipman Hall, Tremont Temple, at 8 P.M.; Vice-President Alexis H. French in the chair; eighty-six members and visitors present.

The record of the last meeting was read and approved.

Messrs. Byron I. Cook, Arthur C. Holt and Leonard L. Street were elected members of the Society.

The sum of $12 was appropriated to meet the incidental expenses of the semi-centennial celebration of the Society.

The thanks of the Society were voted to President Gilbert and other officers of the Boston Electric Light Company for courtesies shown the members of the Society who took part in the excursion to the works of that company this afternoon.

The thanks of the Society were also voted to Mr. J. H. Appleton, of the Riverside Paper Company, to Messrs. Chas. P. Deane and L. E. Bellows, of the Deane Steam Pump Company, to Messrs. E. S. Waters and J. M. Sickman, of the Holyoke Water Power Company, for courtesies shown the Society on the occasion of the visit to Holyoke, Mass., on October 21 and 22.

The Secretary read a letter from Mr. Levi R. Greene, member of the Society, presenting to the Society a portrait of the late Col. George E. Waring. It was voted to accept the gift, and the Secretary was directed to convey the thanks of the Society to the donor.

On motion of Mr. Brooks it was voted that a sum not exceeding $75 be appropriated for the printing of a souvenir pamphlet containing the addresses delivered at the semi-centennial celebration of the Society, provided the Board of Government deem such a publication desirable.

Mr. Stephen Childs then read a paper, entitled "The Maintenance of the System of Separate Sewers in Newton, Mass." A discussion followed on the maintenance of sewers in which Messrs. T. Howard Barnes, William Nelson, Otis F. Clapp and others took part. The Secretary read a short discussion on the same subject prepared by Mr. Bertram Brewer.

Adjourned.

S. E. TINKHAM, *Secretary.*

Engineers' Club of St. Louis.

480TH MEETING, DECEMBER 7, 1898.—The meeting was called to order at 8.15 P.M.; with President Bryan in the chair. Thirty-four members and nineteen visitors were present. Sixteen of these visitors were ladies.

The minutes of the 479th regular meeting and the 265th meeting of the Executive Committee were read and approved.

The Secretary announced that he had received application for membership from Mr. William Fry Scott. The Executive Committee having reported favorably upon the application for membership of Mr. Mark Bary, this gentleman was balloted for and elected a member of the Club.

This being the annual meeting, reports were called for from the officers and standing committees. Reports were read from the following officers and committees: Secretary, Treasurer, Librarian, Board of Managers of the Association of Engineering Societies, Entertainment Committee and Executive Committee. The report of the Treasurer was referred to the Executive Committee for verification, and the other reports were ordered to be received and filed.

As the Committee on Standard Gauges for Thickness had no report to make, this committee was honorably discharged.

The Committee on Nominations reported the following nominations for officers for 1899:

For President—B. H. Colby.

For Vice-President—F. E. Nipher.

For Secretary—E. R. Fish.

For Treasurer—Thos. B. McMath.

For Librarian—E. J. Jolley.

For Directors—S. E. Freeman and J. H. Kinealy.

For members of the Board of Managers of the Journal of the Association of Engineering Societies—J. B. Johnson and Richard McCulloch.

On motion, the meeting was adjourned for five minutes to consider the report of the Committeee on Nominations.

When the meeting again convened, the following additional nominations were made:

For Vice-President—M. L. Holman, Ed. Flad and J. B. Johnson.

For Secretary—Henry Branch.

For Treasurer—E. H. Connor.

For Directors—A. H. Zeller and John A. Laird.

The President stated that in the absence of any objection, the Executive Committee would arrange for the annual supper to be held at the next meeting, December 21, 1898.

The paper of the evening, by Mr. A. H. Zeller, was then read. The author was a delegate from the Engineers' Club of St. Louis to the celebration of the Fiftieth Anniversary of the Civil Engineers of France, and the paper described the manner in which the event was celebrated. He gave an account of the excursions on which the visitors were taken and described the works of engineering interest which were visited. After the reading of the paper, a number of lantern slides were exhibited, showing views of engineering works in Paris, Berlin and other European cities.

A motion was made and carried that the Club make acknowledgment for the handsome manner in which its delegates were entertained, and that the thanks of the Club be extended to the delegates for their services in the celebration.

The Club then adjourned to the library, where refreshments were served and an informal reception held.

Richard McCulloch, *Secretary.*

481st Meeting, December 21, 1898.—The annual dinner was held at the Mercantile Club, at 8.15 o'clock. Forty-one members and eighteen visitors were present. After the dinner had been served, the meeting was called to order by President Bryan, who announced that the result of the letter ballot for officers for 1899 had been as follows:

President—B. H. Colby.

Secretary—E. R. Fish.

Treasurer—Thos. B. McMath.

Librarian—E. J. Jolley.

Directors—J. H. Kinealy and John A. Laird.

Members of the Board of Managers of the Association of Engineering Societies—J. B. Johnson and Richard McCulloch.

There was no one elected Vice-President, as none of the candidates had received a majority of the votes cast.

In the absence of the newly-elected President, Mr. B. H. Colby, Mr. Wm. H. Bryan retained the chair during the remainder of the evening.

The first toast on the program, "The Engineer of To-day," was discussed by Mr. Wm. H. Bryan. The speaker enumerated some of the difficulties which lie in the path of the engineer and pointed out the brilliant achievements of the master minds of the profession.

Col. E. J. Spencer spoke on "Our Late Unpleasantness." Col. Spencer gave a short sketch of the progress of the Cuban war, and paid a brilliant tribute to the patriotism of the American people. Taking into account the preparations which were necessary, and the scarcity of armament and supplies at the beginning of the war, the results were marvelous.

Mr. Richard McCulloch then responded to the toast, "Our Bachelors."

Prof. J. H. Kinealy spoke on the toast, "The Engineer in Mechanics." He stated that the study of mechanics is the basis of all engineering, and that when a student had mastered this subject, he had laid a firm foundation for future work.

The President then called upon Mr. Robert Moore to speak on "The Engineer as a Citizen." Mr. Moore warned engineers not to allow an interest in engineering to absorb their attention so completely as to prohibit them from performing the duties of a good citizen.

Informal remarks were made by Mr. M. L. Holman and Ex-Governor F. A. Tritle, of Arizona.

The meeting then adjourned.

RICHARD MCCULLOCH, *Secretary.*

Detroit Engineering Society.

THE 35TH REGULAR MEETING of the Society was held at the Hotel Ste. Claire, Friday, December 16, 1898, at 8 P.M. Mr. G. Y. Wisner, President of the Society, was in the chair. A letter from the Executive Committee of the League of Associated Engineers with regard to indorsing H. R. Bell, No. 10,403, for reorganizing the personnel of the U. S. Navy, was read by the Secretary. No action was taken by the Society as a body.

The paper of the evening, "The Civil Engineer and National Public Works," was then read by the author, Mr. G. Y. Wisner, President of the Society. The subject was discussed in its various aspects by Messrs. Dow, Goldmark, Keep and Edward Molitor.

Adjourned.

HENRY GOLDMARK, *Secretary.*

A MEETING of the Executive Committee was held at 34 Congress street, West, Friday, December 16, 1898. Present, Messrs. Wisner, Keep, Pope and Goldmark.

The following bills were approved and ordered paid:

Association of Engineering Societies	$22.75
Richmond & Backus Co., stationery	8.85
Henry Goldmark, Secretary, postage	1.50
Total	$33.10

It was voted that Mr. G. Y. Wisner's paper, entitled "The Civil Engineer and National Public Works," be printed in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES. The resignation of Mr. A. B. Atwater was accepted, to take effect at the end of the present fiscal year.

Mr. W. A. Livingstone having expressed a desire to retire from the position of representative of the Society on the Board of Managers of the Association of Engineering Societies, Mr. Gardner S. Williams was appointed in his place.

Adjourned.

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